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<p>(21) International Application Number: PCT/US92/08246 (22) International Filing Date: 28 September 1992 (28.09.92) (30) Priority data: 769,615 1 October 1991 (01.10.91) US (71) Applicant: PROCTER & GAMBLE PHARMACEUTICALS, INC. [US/US]; 17 Eaton Avenue, Norwich, NY 13815 (US). (72) Inventors: WHITE, Ronald, Eugene ; RR2, Box 264, Norwich, NY 13815 (US). DEMUTH, Thomas, Prosser, Jr. ; 10800 Stockbridge Lane, Montgomery, OH 45249 (US).</p>	<p>(74) Agents: REED, T., David et al.; The Procter & Gamble Company, 5299 Spring Grove Avenue, Cincinnati, OH 45202 (US). (81) Designated States: AU, BB, BG, BR, CA, CS, FI, HU, JP, KP, KR, LK, MG, MN, MW, NO, PL, RO, RU, SD, European patent (AT, BE, CH, DE, DK, ES, FR, GB, GR, IE, IT, LU, MC, NL, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, SN, TD, TG). Published With international search report.</p>	
<p>(54) Title: PROCESS FOR MAKING ANTIMICROBIAL QUINOLONYL LACTAMS</p> <p>(57) Abstract</p> <p>The present invention provides methods of making compounds of the structure [Q - L¹] - L - [L² - B], wherein Q is a quinolone moiety; B is a beta-lactam moiety; L, L¹, and L² together comprise a carbamate-containing linking moiety, comprising the steps of: 1) reacting a lactam compound of the formula B-L⁴-H with phosgene to form an intermediate compound of the formula B-L⁴-C(=O)-Cl, where L⁴ is oxygen; and 2) coupling said intermediate compound with a quinolone compound of the formula Q-L³-R⁴⁴, wherein L³ is nitrogen; R⁴⁴ is hydrogen, Si(R⁴⁵)₃, or Sn(R⁴⁵)₃; and R⁴⁵ is lower alkyl. Preferably, the process additionally comprises steps prior to the reacting and coupling steps where esters of the lactam and quinolone compounds are made. Also preferably, the coupling step comprises adding a solution containing the quinolone compound to a solution containing the intermediate compound. The process steps are also preferably performed at a temperature of from about -80 °C to about 0 °C. Preferred antimicrobial compounds made by these processes are those where the beta-lactam moiety is a penem.</p>		

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PROCESS FOR MAKING ANTIMICROBIAL QUINOLONYL LACTAMS

BACKGROUND OF THE INVENTION

5 This invention relates to processes for making antimicrobial compounds. The compounds made by this invention contain, as integral substituents, a quinolone moiety and a lactam-containing moiety.

10 The chemical and medical literature describes a myriad of compounds that are said to be antimicrobial, i.e., capable of destroying or suppressing the growth or reproduction of microorganisms, such as bacteria. In particular, antibacterials include a large variety of naturally-occurring (antibiotic), synthetic, or semi-synthetic compounds. They may be classified
15 (for example) as the aminoglycosides, ansamacrolides, beta-lactams (including penicillins and cephalosporins), lincosaminides, macrolides, nitrofurans, nucleosides, oligosaccharides, peptides and polypeptides, phenazines, polyenes, polyethers, quinolones, tetracyclines, and sulfonamides. Such antibacterials
20 and other antimicrobials are described in Antibiotics, Chemotherapeutics, and Antibacterial Agents for Disease Control (M. Grayson, editor, 1982), and E. Gale et al., The Molecular Basis of Antibiotic Action 2d edition (1981), both incorporated by reference herein.

25 Recently, a new class of highly potent, broad spectrum antimicrobials was discovered, combining beta-lactam moieties with quinolone moieties. These compounds have been referred to as "Quinolonyl Lactam Antimicrobials" (herein referred to as "QLAs)." Such compounds are described in European Patent
30 Publication 366,189, White and Demuth, published May 2, 1990; European Patent Publication 366,193, Demuth and White, published

May 2, 1990; European Patent Publication 366,640, Demuth and White, published May 2, 1990; and European Patent Publication 366, 641, White and Demuth, published May 2, 1990. Other such compounds are described in Australian Patent Publication 87/75009, Albrecht et al., published January 7, 1988; Australian Patent Publication 88/27554, published June 6, 1989; European Patent Publication 335, 297, Albrecht et al., published October 4, 1989; and Albrecht et al., "Dual-Action Cephalosporins: Cephalosporin 3'-Quinolone Carbamates", 34 J. Medicinal Chemistry 2857 (1991).

Manufacture of QLAs generally involves synthesis of suitably protected substituent beta-lactam and quinolone moieties, a linking process, and appropriate de-protection steps. The specific linking process depends, of course, on the specific lactam and quinolone substituent moieties used, as well as the type of linkage desired. Several such linking processes have been described in the literature. However, the yields of these processes are often low, particularly for the preparation of QLAs having a penem substituent moiety.

It has now been discovered that certain linking processes using phosgene are useful in making QLAs, particularly those having a penem substituent moiety. Such processes allow efficient synthesis of QLAs, with high yields.

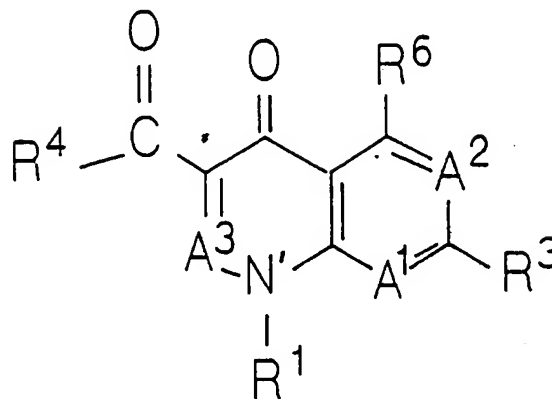
SUMMARY OF THE INVENTION

The present invention provides methods of making compounds of the structure



wherein

(I) Q is a structure according to Formula (I)



wherein

(A) (1) A¹ is N or C(R⁷); where

(i) R⁷ is hydrogen, hydroxy, alkoxy, nitro, cyano, halogen, alkyl, or N(R⁸)(R⁹), and

(ii) R⁸ and R⁹ are, independently, R^{8a} where R^{8a} is hydrogen, alkyl, alkenyl, carbocyclic ring, or heterocyclic ring; or R⁸ and R⁹ together comprise a heterocyclic ring including the nitrogen to which they are bonded;

(2) A² is N or C(R²); where R² is hydrogen or halogen;

(3) A³ is N or C(R⁵); where R⁵ is hydrogen;

(4) R¹ is hydrogen, alkyl, a carbocyclic ring, a heterocyclic ring, alkoxy, hydroxy, alkenyl, arylalkyl, or N(R⁸)(R⁹);

(5) R³ is hydrogen, halogen, alkyl, a carbocyclic ring, or a heterocyclic ring;

(6) R⁴ is hydroxy; and

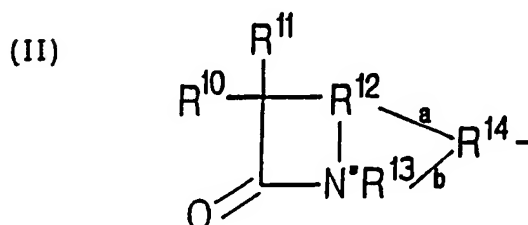
(7) R⁶ is hydrogen, halogen, nitro or N(R⁸)(R⁹);

(B) except that

(1) when A¹ is C(R⁷), R¹ and R⁷ may together comprise a heterocyclic ring including N' and A¹;

- (2) when A^2 is $C(R^2)$, R^2 and R^3 may together comprise $-O-(CH_2)_n-O-$, where n is an integer from 1 to 4;
- (3) when A^3 is $C(R^5)$, R^4 and R^5 may together comprise a heterocyclic ring including the carbon atoms to which R^4 and R^5 are bonded and the carbon atom of Formula (I) to which said carbon atoms are bonded; and
- (4) when A^3 is $C(R^5)$, R^1 and R^5 may together comprise a heterocyclic ring including N' and the adjacent carbon to which R^5 is bonded;
- (C) and except that one of R^1 , R^6 , or R^7 must be nil;

(II) B is a structure according to Formula (II):



wherein

- (A) R^{10} is hydrogen, halogen, alkyl, alkenyl, heteroalkyl, a carbocyclic ring, a heterocyclic ring, R^8a-O- , $R^8aCH=N-$, $(R^8)(R^9)N-$, $R^{17}-C(=CHR^{20})-C(=O)NH-$, $R^{17}-C(=NO-R^{19})-C(=O)NH-$, or $R^{18}-(CH_2)_m-C(=O)NH-$; where
- (1) m is an integer from 0 to 9;
- (2) R^{17} is hydrogen, alkyl, alkenyl, heteroalkyl, heteroalkenyl, a carbocyclic ring, or a heterocyclic ring;
- (3) R^{18} is R^{17} , $-Y^1$, or $-CH(Y^2)(R^{17})$;
- (4) R^{19} is R^{17} , arylalkyl, heteroarylalkyl, $-C(R^{22})(R^{23})COOH$, $-C(=O)O-R^{17}$, or

-C(=O)NH-R¹⁷, where R²² and R²³ are, independently, R¹⁷ or together comprise a carbocyclic ring or a heterocyclic ring including the carbon atom to which R²² and R²³ are bonded;

(5) R²⁰ is R¹⁹, halogen, -Y¹, or -CH(Y²)(R¹⁷);

(6) Y¹ is -C(=O)OR²¹, -C(=O)R²¹, -N(R²⁴)R²¹, -S(O)_pR²⁹, or -OR²⁹; and Y² is Y¹ or -OH, -SH, or -SO₃H;

(a) p is an integer from 0 to 2;

(b) R²⁴ is hydrogen; alkyl; alkenyl; heteroalkyl; heteroalkenyl; a carbocyclic ring; a heterocyclic ring; -SO₃H; -C(=O)R²⁵; or, when R¹⁸ is -CH(N(R²⁴)R²¹)(R¹⁷), R²⁴ may comprise a moiety bonded to R²¹ to form a heterocyclic ring; and

(c) R²⁵ is R¹⁷, NH(R¹⁷), N(R¹⁷)(R²⁶), O(R²⁶), or S(R²⁶); where R²⁶ is alkyl, alkenyl, a carbocyclic ring, a heterocyclic ring, or when R²⁵ is N(R¹⁷)(R²⁶), R²⁶ may be a moiety bonded to R¹⁷ to form a heterocyclic ring; and

(7) R²¹ is R²⁹ or hydrogen; where R²⁹ is alkyl; alkenyl; arylalkyl; heteroalkyl; heteroalkenyl; heteroarylalkyl; a carbocyclic ring; a heterocyclic ring; or, when Y is N(R²⁴)R²¹ and R²¹ is R²⁹, R²¹ and R²⁴ may together comprise a heterocyclic ring including the nitrogen atom to which R²⁴ is bonded;

(B) R¹¹ is hydrogen, halogen, alkoxy, or R²⁷C(=O)NH-, where R²⁷ is hydrogen or alkyl;

(C) bond "a" is a single bond or is nil; and bond "b" is a single bond, a double bond, or is nil; except bond "a" and bond "b" are not both nil;

(D) R¹² is -C(R^{8a})-, or -CH₂-R²⁸-; where R²⁸ is -C(R^{8a}), -O-, or -N-, and R²⁸ is directly bonded to N" in Formula (II) to form a 5-membered ring; except, if bond "a" is nil, then R¹² is

5

(1) -C(R^{8a})(X¹)-, where

(i) X¹ is -R²¹; -OR³⁰; -S(O)_rR³⁰, where r is an integer from 0 to 2; -OC(=O)R³⁰; or N(R³⁰)R³¹; and

10

(ii) R³⁰ and R³¹ are, independently, alkyl, alkenyl, carbocyclic ring or heterocyclic ring substituents; or R³⁰ and R³¹ together comprise a heterocyclic ring including the nitrogen atom to which R³⁰ and R³¹ are bonded; or

15

(2) -CH₂-R³²-; where R³² is -C(R^{8a})(R²¹), -O-, or -NR^{8a}, and R³² is directly bonded to N" in Formula (II) to form a 5-membered ring;

(E) (1) if bond "b" is a single bond, R¹³ is -CH(R³³)-; or, -C(O)NHSO₂-, if bond "a" is nil; or -C*(R³³)- if R¹⁴ contains a R³⁶ moiety; where R³³ is hydrogen or COOH, and C* is linked to R³⁶ to form a 3-membered ring;

20

(2) if bond "b" is a double bond, R¹³ is -C(R³³)=; or

25

(3) if bond "b" is nil, R¹³ is hydrogen, -SO₃H, -PO(OR³⁴)OH, -C(O)NHSO₂N(R³⁴)(R³⁵), -OSO₃H, -CH(R³⁵)COOH, or -OCH(R³⁴)COOH; where R³⁴ is hydrogen, alkyl, alkenyl, a carbocyclic ring, or a heterocyclic ring; and R³⁵ is hydrogen, alkyl, alkenyl, or -NHR^{8a}; or, if R¹³ is -C(O)NHSO₂N(R³⁴)(R³⁵), R³⁴ and R³⁵ may together comprise a heterocyclic ring including the nitrogen to which R³⁴ and R³⁵ are bonded; and

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(F) (1) if bond "a" or bond "b" is nil, then R¹⁴ is nil;

(2) if bond "a" and "b" are single bonds, R¹⁴ is -W-C''=C(R^{8a})-R³⁷-, or -W-C''(R³⁶)-R³⁷-; or

(3) if bond "a" is a single bond and bond "b" is a double bond, R¹⁴ is -C(R^{8a})(R³⁸)-W-C''-R³⁷-; -W'-C(R^{8a})(R³⁸)-C''-R³⁷-; or -W-C''-R³⁷-;

where

(a) W is 0; S(0)_s, where s is an integer from 0 to 2; or C(R³⁸), where R³⁸ is hydrogen, alkyl or alkoxy;

(b) W' is 0; or C(R³⁸);

(c) R³⁶ hydrogen; alkyl; alkenyl; -COOH; or, if R¹³ is -C*(R³³), R³⁶ may be linked to C* to form a 3-membered carbocyclic ring;

(d) R³⁷ and is nil, alkyl, alkenyl, a carbocyclic ring, or a heterocyclic ring; and

(e) C'' is directly bonded to R¹³ to form a 5- or 6-membered ring; and

(III)(A) L is -C(=O)-, and is bonded to L³ and L⁴

(B) L¹ is L³ or R¹⁵L³; where

(1) L³ is nitrogen;

(2) R¹⁵ is alkyl, alkenyl, heteroalkyl, a heterocyclic ring, a carbocyclic ring, or R¹⁵ together with L³ is a heteroalkyl or a heterocyclic ring; and

(3) L¹ is bonded to Q at the point of attachment of R¹, R⁶ or R⁷, whichever is nil;

(C) L² is L⁴, -X²_t-R³⁹-L⁴, or -X³_t-R³⁹-L⁴; where

(1) L⁴ is oxygen;

(2) X² is oxygen, or S(0)_v, where v is 0, 1, or 2;

(3) X³ is nitrogen; N(R⁴⁰); N⁺(R⁴¹)(R⁴²); or R⁴³-N(R⁴¹); and is linked to R¹⁴ by a single

or double bond; or, if R¹⁴ is nil, X³ is linked to B by a single or double bond; where

(a) R⁴⁰ is R^{8a}; -OR^{8a}; or -C(=O)R^{8a};

(b) R⁴¹ and R⁴² are, independently, hydrogen; alkyl; alkenyl; carbocyclic rings; heterocyclic rings; or, if R⁶ is R^{16x}, then R⁴¹ and R⁴² together with Qⁿ may comprise a heterocyclic ring as R¹⁶;

(c) R⁴³ is N(R⁴¹), oxygen or sulfur;

(4) t is 0 or 1;

(5) R³⁹ is alkyl, alkenyl, heteroalkyl, heteroalkenyl, a carbocyclic ring, or a heterocyclic ring; and

(6) (a) if bond "a" or bond "b" is nil, then L² is bonded directly to R¹² or R¹³; or

(b) if bond "a" and bond "b" are not nil, then L² is bonded to R¹⁴;

and pharmaceutically-acceptable salts and biohydrolyzable esters thereof, and hydrates thereof;

comprising the steps of:

(1) Reacting a lactam compound of the formula B-L⁴-H with phosgene to form an intermediate compound of the formula B-L⁴-C(=O)-Cl; and

(2) Coupling said intermediate compound with a quinolone compound of the formula Q-L³-R⁴⁴; wherein R⁴⁴ is hydrogen, Si(R⁴⁵)₃, or Sn(R⁴⁵)₃; and R⁴⁵ is lower alkyl.

Preferably, the process additionally comprises steps prior to the reacting and coupling steps where esters of the lactam and quinolone compounds are made. Also preferably, the coupling step comprises adding a solution containing the quinolone compound to a solution containing the intermediate compound. The process steps are also preferably performed at a temperature of from about -80° C to about 0° C. Preferred antimicrobial compounds

made by these processes are those where R¹⁴ is -W-C''-R³⁷-, more preferably wherein W is S(O)₂.

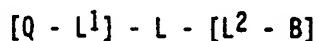
DESCRIPTION OF THE INVENTION

5 The present invention encompasses methods for making certain QLAs. These compounds are useful for treating infectious disorders in humans or other animal subjects. Thus, the compounds made by this invention must be pharmaceutically acceptable. As used herein, such a "pharmaceutically-acceptable" component is one that is suitable for use with humans and/or animals without undue adverse side effects (such as toxicity, irritation, and allergic response) commensurate with a reasonable benefit/risk ratio.

QLAs

15 The compounds ("QLAs") made by the methods of this invention encompass any of a variety of lactam moieties linked, by a linking moiety, to a quinolone moiety at the 1-, 5-, or 7-position of the quinolone. These compounds include those having the general formula

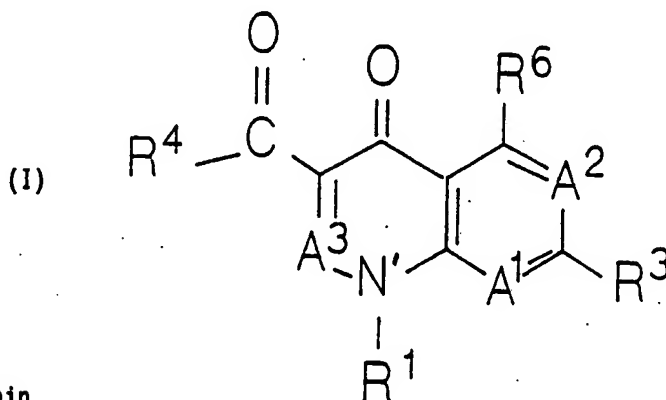
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wherein

(I) Q is a structure according to Formula (I)

25



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wherein

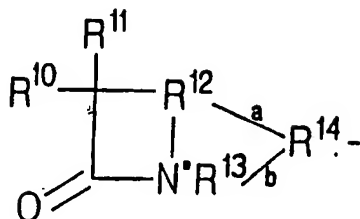
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(A) (1) A¹ is N or C(R⁷); where

- (i) R^7 is hydrogen, hydroxy, alkoxy, nitro, cyano, halogen, alkyl, or $N(R^8)(R^9)$ (preferably hydrogen or halogen), and
- (ii) R^8 and R^9 are, independently, R^{8a} where R^{8a} is hydrogen, alkyl, alkenyl, carbocyclic ring, or heterocyclic ring; or R^8 and R^9 together comprise a heterocyclic ring including the nitrogen to which they are bonded;
- (2) A^2 is N or (preferably) $C(R^2)$; where R^2 is hydrogen or halogen;
- (3) A^3 is N or (preferably) $C(R^5)$; where R^5 is hydrogen;
- (4) R^1 is hydrogen, alkyl, a carbocyclic ring, a heterocyclic ring, alkoxy, hydroxy, alkenyl, arylalkyl, or $N(R^8)(R^9)$ (preferably alkyl or a carbocyclic ring);
- (5) R^3 is hydrogen, halogen, alkyl, a carbocyclic ring, or a heterocyclic ring (preferably a heterocyclic ring);
- (6) R^4 is hydroxy; and
- (7) R^6 is hydrogen, halogen, nitro or $N(R^8)(R^9)$;
- (B) except that
- (1) when A^1 is $C(R^7)$, R^1 and R^7 may together comprise a heterocyclic ring including N' and A^1 ;
- (2) when A^2 is $C(R^2)$, R^2 and R^3 may together comprise $-O-(CH_2)_n-O-$, where n is an integer from 1 to 4;
- (3) when A^3 is $C(R^5)$, R^4 and R^5 may together comprise a heterocyclic ring including the carbon atoms to which R^4 and R^5 are bonded and the carbon atom of Formula (I) to which said carbon atoms are bonded; and
- (4) when A^3 is $C(R^5)$, R^1 and R^5 may together comprise a heterocyclic ring including N' and the adjacent carbon to which R^5 is bonded;
- (C) and except that one of R^1 , R^6 , or R^7 must be nil;

(II) B is a structure according to Formula (II):

(II)



wherein

(A) R¹⁰ is hydrogen, halogen, heteroalkyl, a carbocyclic ring, a heterocyclic ring, R^{8a}-O-, R^{8a}CH=N-, (R⁸)(R⁹)N-, R¹⁷-C(=CHR²⁰)-C(=O)NH-, or (preferably) alkyl, alkenyl, R¹⁷-C(=NO-R¹⁹)-C(=O)NH-, or R¹⁸-(CH₂)_m-C(=O)NH-; where

(1) m is an integer from 0 to 9 (preferably from 0 to 3);

(2) R¹⁷ is hydrogen, alkyl, alkenyl, heteroalkyl, heteroalkenyl, a carbocyclic ring, or a heterocyclic ring (preferably alkyl, a carbocyclic ring, or a heterocyclic ring);

(3) R¹⁸ is R¹⁷, -Y¹, or -CH(Y²)(R¹⁷);

(4) R¹⁹ is R¹⁷, arylalkyl, heteroarylalkyl, -C(R²²)(R²³)COOH, -C(=O)O-R¹⁷, or -C(=O)NH-R¹⁷, where R²² and R²³ are, independently, R¹⁷ or together comprise a carbocyclic ring or a heterocyclic ring including the carbon atom to which R²² and R²³ are bonded (preferably R¹⁷ or -C(R²²)(R²³)COOH);

(5) R²⁰ is R¹⁹, halogen, -Y¹, or -CH(Y²)(R¹⁷) (preferably R¹⁹ or halogen);

(6) Y¹ is -C(=O)OR²¹, -C(=O)R²¹, -N(R²⁴)R²¹, -S(O)_pR²⁹, or -OR²⁹; and Y² is Y¹ or -OH, -SH, or -SO₃H;

(a) p is an integer from 0 to 2 (preferably 0);

- (b) R²⁴ is hydrogen; alkyl; alkenyl; heteroalkyl; heteroalkenyl; a carbocyclic ring; a heterocyclic ring; -SO₃H; -C(=O)R²⁵; or, when R¹⁸ is -CH(N(R²⁴)R²¹)(R¹⁷), R²⁴ may comprise a moiety bonded to R²¹ to form a heterocyclic ring; and
- (c) R²⁵ is R¹⁷, NH(R¹⁷), N(R¹⁷)(R²⁶), O(R²⁶), or S(R²⁶) (preferably R¹⁷, NH(R¹⁷), N(R¹⁷)(R²⁶)); where R²⁶ is alkyl, alkenyl, a carbocyclic ring, a heterocyclic ring, or (preferably) when R²⁵ is N(R¹⁷)(R²⁶), R²⁶ may be a moiety bonded to R¹⁷ to form a heterocyclic ring; and
- (7) R²¹ is R²⁹ or hydrogen; where R²⁹ is alkyl; alkenyl; arylalkyl; heteroalkyl; heteroalkenyl; heteroarylalkyl; a carbocyclic ring; a heterocyclic ring; or, when Y is N(R²⁴)R²¹ and R²¹ is R²⁹, R²¹ and R²⁴ may together comprise a heterocyclic ring including the nitrogen atom to which R²⁴ is bonded (preferably hydrogen, alkyl, a carbocyclic ring, or a heterocyclic ring);
- (B) R¹¹ is hydrogen, halogen, alkoxy, or R²⁷C(=O)NH- (preferably hydrogen or alkoxy), where R²⁷ is hydrogen or alkyl (preferably hydrogen);
- (C) bond "a" is a single bond or is nil; and bond "b" is a single bond, a double bond, or is nil; except bond "a" and bond "b" are not both nil;
- (D) R¹² is -C(R^{8a})-, or -CH₂-R²⁸- (preferably -C(R^{8a})-); where R²⁸ is -C(R^{8a}), -O-, or -N-, and R²⁸ is directly bonded to N" in Formula (II) to form a 5-membered ring; except, if bond "a" is nil, then R¹² is
- (1) (preferably) -C(R^{8a})(X¹)-, where
- (i) X¹ is -R²¹; -OR³⁰; -S(O)_rR³⁰, where r is an integer from 0 to 2 (preferably 0); -OC(=O)R³⁰; or N(R³⁰)R³¹; and
- (ii) R³⁰ and R³¹ are, independently, alkyl, alkenyl, carbocyclic ring or heterocyclic ring substituents; or R³⁰ and R³¹ together comprise a

heterocyclic ring including the nitrogen atom to which R³⁰ and R³¹ are bonded; or

(2) -CH₂-R³²-; where R³² is -C(R^{8a})(R²¹), -O-, or -NR^{8a}, and R³² is directly bonded to N¹ in Formula (II) to form a 5-membered ring;

(E) (1) if bond "b" is a single bond, R¹³ is (preferably) -CH(R³³)-; or, -C(O)NHSO₂-, if bond "a" is nil; or -C*(R³³)- if R¹⁴ contains a R³⁶ moiety; where R³³ is hydrogen or (preferably) COOH, and C* is linked to R³⁶ to form a 3-membered ring;

(2) if bond "b" is a double bond, R¹³ is -C(R³³)=; or

(3) if bond "b" is nil, R¹³ is hydrogen, -SO₃H, -PO(OR³⁴)OH, -C(O)NHSO₂N(R³⁴)(R³⁵), -OSO₃H, -CH(R³⁵)COOH, or -OCH(R³⁴)COOH (preferably -SO₃H or -C(O)NHSO₂N(R³⁴)(R³⁵)); where R³⁴ is hydrogen, alkyl, alkenyl, a carbocyclic ring, or a heterocyclic ring; and R³⁵ is hydrogen, alkyl, alkenyl, or -NHR^{8a}; or (preferably), if R¹³ is -C(O)NHSO₂N(R³⁴)(R³⁵), R³⁴ and R³⁵ may together comprise a heterocyclic ring including the nitrogen to which R³⁴ and R³⁵ are bonded; and

(F) (1) if bond "a" or bond "b" is nil, then R¹⁴ is nil;

(2) if bond "a" and "b" are single bonds, R¹⁴ is -W-C''=C(R^{8a})-R³⁷-, or -W-C''(R³⁶)-R³⁷-, or

(3) (preferably) if bond "a" is a single bond and bond "b" is a double bond, R¹⁴ is -C(R^{8a})(R³⁸)-W-C''-R³⁷-, or (preferably) -W'-C(R^{8a})(R³⁸)-C''-R³⁷-, or -W-C''-R³⁷-, where

(a) W is O; S(O)_s, where s is an integer from 0 to 2 (preferably 0); or C(R³⁸), where R³⁸ is hydrogen, alkyl or alkoxy;

(b) W' is O; or C(R³⁸);

(c) R³⁶ hydrogen; alkyl; alkenyl; -COOH; or, if R¹³ is -C*(R³³), R³⁶ may be linked to C* to form a 3-membered carbocyclic ring;

- (d) R³⁷ and is nil, alkyl, alkenyl, a carbocyclic ring, or a heterocyclic ring; and
(e) C'' is directly bonded to R¹³ to form a 5- or 6-membered ring; and

5

(III)(A) L is -C(=O)-, and is bonded to L³ and L⁴

(B) L¹ is L³ or R¹⁵L³; where

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- (1) L³ is nitrogen;
(2) R¹⁵ is alkyl, alkenyl, heteroalkyl, a heterocyclic ring, a carbocyclic ring, or R¹⁵ together with L³ is a heteroalkyl or a heterocyclic ring;
(3) L¹ is bonded to Q at the point of attachment of R¹, R⁶ or R⁷, whichever is nil;

(C) L² is L⁴, -X²_t-R³⁹-L⁴, or -X³_t-R³⁹-L⁴; where

15

- (1) L⁴ is oxygen;
(2) X² is oxygen, or S(O)_v, where v is 0, 1, or 2;
(3) X³ is nitrogen; N(R⁴⁰); N⁺(R⁴¹)(R⁴²); or R⁴³-N(R⁴¹); and is linked to R¹⁴ by a single or double bond; or, if R¹⁴ is nil, X³ is linked to B by a single or double bond (preferably X³ is nitrogen, N(R⁴⁰), or N⁺(R⁴¹)(R⁴²)); where

20

(a) R⁴⁰ is R^{8a}; -OR^{8a}; or -C(=O)R^{8a} (preferably R^{8a});

(b) R⁴¹ and R⁴² are, independently, hydrogen; alkyl; alkenyl; carbocyclic rings; heterocyclic rings; or, if R⁶ is R¹⁶X, then R⁴¹ and R⁴² together with Q'' may comprise a heterocyclic ring as R¹⁶;

25

(c) R⁴³ is N(R⁴¹), oxygen or sulfur;

30

(4) t is 0 or 1;

(5) R³⁹ is alkyl, alkenyl, heteroalkyl, heteroalkenyl, a carbocyclic ring, or a heterocyclic ring;

(6) (a) if bond "a" or bond "b" is nil, then L² is bonded directly to R¹² or R¹³; or

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(b) if bond "a" and bond "b" are not nil, then L² is bonded to R¹⁴;

and pharmaceutically-acceptable salts and biohydrolyzable esters thereof, and hydrates thereof. Preferred antimicrobial compounds
5 made by the processes of this invention include those where R³ is nil and comprises a bond to L¹, and those where R⁶ is nil and comprises a bond to L¹.

Definitions and Usage of Terms:

10

The following is a list of definitions for terms used herein.

"Heteroatom" is a nitrogen, sulfur or oxygen atom. Groups containing one or more heteroatoms may contain different
15 heteroatoms.

"Alkyl" is an unsubstituted or substituted saturated hydrocarbon chain radical having from 1 to 8 carbon atoms, preferably from 1 to 4 carbon atoms. Preferred alkyl groups include (for example) methyl, ethyl, propyl, isopropyl, and
20 butyl.

"Heteroalkyl" is an unsubstituted or substituted saturated chain radical having from 3 to 8 members comprising carbon atoms and one or two heteroatoms.

"Alkenyl" is an unsubstituted or substituted hydrocarbon
25 chain radical having from 2 to 8 carbon atoms, preferably from 2 to 4 carbon atoms, and having at least one olefinic double bond.

"Carbocyclic ring" is an unsubstituted or substituted, saturated, unsaturated or aromatic, hydrocarbon ring radical. Carbocyclic rings are monocyclic or are fused, bridged or spiro
30 polycyclic ring systems. Monocyclic rings contain from 3 to 9 atoms, preferably 3 to 6 atoms. Polycyclic rings contain from 7 to 17 atoms, preferably from 7 to 13 atoms.

"Cycloalkyl" is a saturated carbocyclic ring radical. Preferred cycloalkyl groups include (for example) cyclopropyl, cyclobutyl and cyclohexyl.
35

"Heterocyclic ring" is an unsubstituted or substituted, saturated, unsaturated or aromatic ring radical comprised of carbon atoms and one or more heteroatoms in the ring. Heterocyclic rings are monocyclic or are fused, bridged or spiro polycyclic ring systems. Monocyclic rings contain from 3 to 9 atoms, preferably 3 to 6 atoms. Polycyclic rings contain from 7 to 17 atoms, preferably from 7 to 13 atoms.

"Aryl" is an aromatic carbocyclic ring radical. Preferred aryl groups include (for example) phenyl, tolyl, xylyl, cumenyl and naphthyl.

"Heteroaryl" is an aromatic heterocyclic ring radical. Preferred heteroaryl groups include (for example) thienyl, furyl, pyrrolyl, pyridinyl, pyrazinyl, thiazolyl, quinolinyl, pyrimidinyl and tetrazolyl.

"Alkoxy" is an oxygen radical having a hydrocarbon chain substituent, where the hydrocarbon chain is an alkyl or alkenyl (i.e., -O-alkyl or -O-alkenyl). Preferred alkoxy groups include (for example) methoxy, ethoxy, propoxy and allyloxy.

"Alkylamino" is an amino radical having one or two alkyl substituents (i.e., -N-alkyl).

"Arylalkyl" is an alkyl radical substituted with an aryl group. Preferred arylalkyl groups include benzyl and phenylethyl.

"Arylamino" is an amine radical substituted with an aryl group (i.e., -NH-aryl).

"Aryloxy" is an oxygen radical having a aryl substituent (i.e., -O-aryl).

"Acyl" or "carbonyl" is a radical formed by removal of the hydroxy from an carboxylic acid (i.e., $R-C(=O)-$). Preferred alkylacyl groups include (for example) acetyl, formyl, and propionyl.

"Acyloxy" is an oxygen radical having an acyl substituent (i.e., -O-acyl); for example, -O-C(=O)-alkyl.

"Acylamino" is an amino radical having an acyl substituent (i.e., -N-acyl); for example, -NH-C(=O)-alkyl.

"Halo", "halogen", or "halide" is a chloro, bromo, fluoro or iodo atom radical. Chloro and fluoro are preferred halides.

Also, as referred to herein, a "lower" hydrocarbon moiety (e.g., "lower" alkyl) is a hydrocarbon chain comprised of from 1 to 6, preferably from 1 to 4, carbon atoms..

A "pharmaceutically-acceptable salt" is a cationic salt formed at any acidic (e.g., carboxyl) group, or an anionic salt formed at any basic (e.g., amino) group. Many such salts are known in the art, as described in World Patent Publication 87/05297, Johnston et al., published September 11, 1987 (incorporated by reference herein). Preferred cationic salts include the alkali metal salts (such as sodium and potassium), and alkaline earth metal salts (such as magnesium and calcium). Preferred anionic salts include the halides (such as chloride salts).

A "biohydrolyzable ester" is an ester of a QLA that does not essentially interfere with the antimicrobial activity of the compounds, or that are readily metabolized by a human or lower animal subject to yield an antimicrobially-active quinolonyl lactam. Such esters include those that do not interfere with the biological activity of quinolone antimicrobials or beta-lactam antimicrobials (cephems, for example). Many such esters are known in the art, as described in World Patent Publication 87/05297, Johnston et al., published September 11, 1987, (incorporated by reference herein). Such esters include lower alkyl esters, lower acyloxy-alkyl esters (such as acetoxymethyl, acetoxylethyl, aminocarbonyloxymethyl, pivaloyloxymethyl and pivaloyloxyethyl esters), lactonyl esters (such as phthalidyl and thiophthalidyl esters), lower alkoxyacyloxyalkyl esters (such as methoxycarbonyloxymethyl, ethoxycarbonyloxyethyl and isopropoxycarbonyloxyethyl esters), alkoxyalkyl esters, choline esters and alkyl acylamino alkyl esters (such as acetamidomethyl esters).

As defined above and as used herein, substituent groups may themselves be substituted. Such substitution may be with one or more substituents. Such substituents include (for example) those

listed in C. Hansch and A. Leo, Substituent Constants for Correlation Analysis in Chemistry and Biology (1979), incorporated by reference herein. Preferred substituents include (for example) alkyl, alkenyl, alkoxy, hydroxy, oxo, nitro, amino, aminoalkyl (e.g., aminomethyl, etc.), cyano, halo, carboxy, alkoxyacyl (e.g., carboethoxy, etc.), thiol, aryl, cycloalkyl, heteroaryl, heterocycloalkyl (e.g., piperidiny, morpholinyl, pyrrolidinyl, etc.), imino, thioxo, hydroxyalkyl, aryloxy, arylalkyl, and combinations thereof.

Also, as used in defining the structure of the compounds of this invention, a particular radical may be defined for use as a substituent in multiple locations. For example, the R^8 substituent is defined as a potential substituent of R^7 , but is also incorporated into the definition of other substituents (such as R^1 , R^6 , and R^{10} . As used herein, such a radical is independently selected each time it is used (e.g., R^8 need not be alkyl in all occurrences in defining a given compound of this invention).

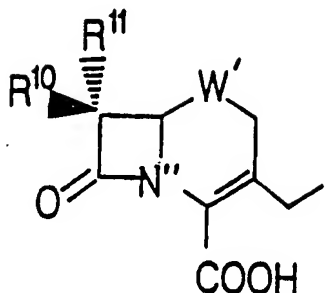
Lactam-containing moiety:

Groups R^{12} , R^{13} , and R^{14} , together with bonds "a" and "b" of formula (I), form any of a variety of lactam-containing moieties known in the art to have antimicrobial activity. Such moieties wherein either bond "a" or bond "b" are nil (i.e., do not exist) are mono-cyclic; if both bonds exist, the structures are bi-cyclic. Preferably, bond "a" is a single bond and bond "b" is a double bond.

Preferred lactam moieties include the oxacephems and carbacephems of the representative formula:

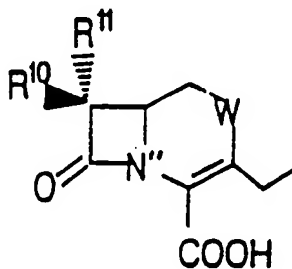
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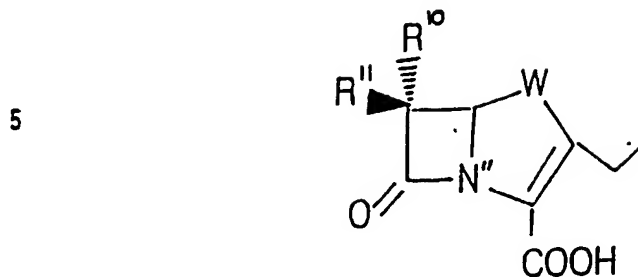
10 wherein, referring to formula (II), bond "a" is a single bond;
bond "b" is a double bond; R12 is -C(R8a)-, where R8a is
hydrogen; R13 is -CH(R33), where R33 is COOH; and R14 is
-W'-C(R8a)(R38)-C''-R37, where R8a and R38 are hydrogen, R37 is
15 methylene, and W' is O (for oxacephems) or C(R38) (for
carbacephems).

Other preferred lactam moieties include the isocephems and
iso-oxacephems of the representative formula:



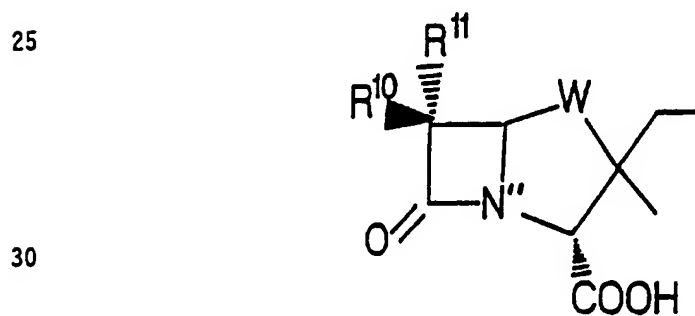
20 wherein, referring to formula II, bond "a" is a single bond; bond
"b" is a double bond; R12 is -C(R8a) where R8a is hydrogen; R13
is -C(R33)=, where R33 is COOH; and R14 is -C(R8a)(R38)-W-C''-R37
25 where R8a and R38 are each hydrogen, R37 is methylene, and W is S
(for isocephems) or O (for iso-oxacephems).

Other preferred lactam-containing moieties include the
penems, carbapenems and clavams, of the representative formula:



10 wherein, referring to formula (II), bond "a" is a single bond; bond "b" is a double bond; R¹² is -C(R^{8a}), where R^{8a} is hydrogen; R¹³ is -C(R³³)=, where R³³ is COOH; and R¹⁴ is -W-C''-R³⁷, where R³⁷ is methylene, and W is S (for penems), C(R³⁸) (for carbapenems), or O (for clavams). Such lactam moieties are described in the following articles, all incorporated by reference herein: R. Wise, "In Vitro and Pharmacokinetic Properties of the Carbapenems", 30 Antimicrobial Agents and
 15 Chemotherapy 343 (1986); and S. McCombie et al., "Synthesis and In Vitro Activity of the Penem Antibiotics", 8 Medicinal Research
 20 Reviews 393 (1988).

Other preferred lactam-containing moieties of this invention include the penicillins of the representative formula:

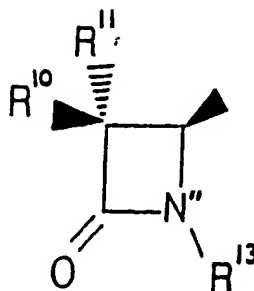


wherein, referring to formula II, bond "a" is a single bond, bond "b" is a single bond; R¹² is -C(R^{8a})-, where R^{8a} is hydrogen; R¹³ is -CH(R³³)- where R³³ is COOH; and R¹⁴ is -W-C''(R³⁶)-R³⁷- where R³⁶ is methyl, R³⁷ is methylene, and W is S.

Other preferred lactam-containing moieties include the monocyclic beta-lactams, of the representative formula:

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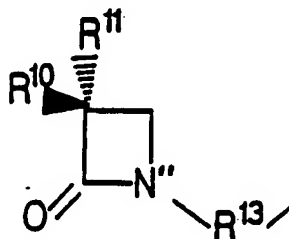


wherein, referring to formula (II), bond "a" is a single bond; bond "b" is nil; R¹² is -C(R^{8a})-, where R^{8a} is hydrogen; R¹⁴ is nil; and R¹³ is -SO₃H (for a monobactam), -PO(OR³⁴)OH (for a monophospham); -C(O)NHSO₂N(R³⁴)(R³⁵) (for a monocarbam), -OSO₃H (for a monosulfactam), -CH(R³⁵)COOH (for nocardicins), or -OCH(R³⁴)COOH. Such lactam moieties are described in C. Cimarusti et al., "Monocyclic 8-lactam Antibiotics", 4 Medicinal Research Reviews 1 (1984), incorporated by reference herein.

Other preferred lactam moieties include the monocyclic beta-lactams of the representative formula:

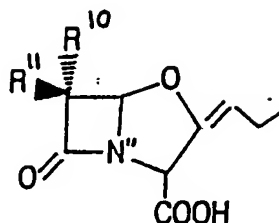
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wherein referring to formula II, bond "a" is nil, bond "b" is a single bond; R¹² is -C(R^{8a})(R²⁹)- where both R^{8a} and R²⁹ are hydrogen; and R¹⁴ is nil.

Other preferred lactam moieties include the clavams of the representative formula:

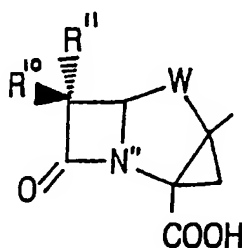


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wherein, referring to formula (II), bond "a" is a single bond; bond "b" is a single bond; R¹² is -C(R^{8a})-, where R^{8a} is hydrogen; R¹³ is -CH(R³³)-, where R³³ is COOH; and R¹⁴ is W-C''=C-(R^{8a})-R³⁷, where R^{8a} is hydrogen and R³⁷ is methylene, and W is O.

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Other preferred lactam moieties include the 2,3-methylenopenams and -carbapenams of the representative formula:



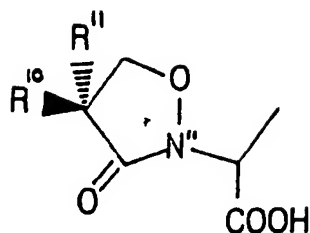
wherein, referring to formula (II), bond "a" is a single bond; bond "b" is a single bond; R¹² is -C(R^{8a})-, where R^{8a} is hydrogen; R¹³ is -C*(R³³), where R³³ is COOH; and R¹⁴ is W-C''(R³⁶)-R³⁷, where R³⁷ is nil, R³⁶ is linked to C* to form a 3-membered carbocyclic ring, and W is C(R³⁸) or sulfur.

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Lactam moieties of this invention also include the lactivicin analogs of the representative formula:

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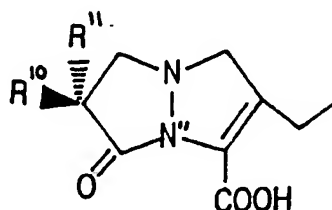
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10 wherein, referring to formula (II), bond "a" is nil; bond "b" is a single bond; R¹² is -CH₂-R³², where R³² is O; R¹³ is -CH(R³³)-, where R³³ is COOH; and R¹⁴ is nil.

Other lactam moieties include the pyrazolidinones of the representative formula:

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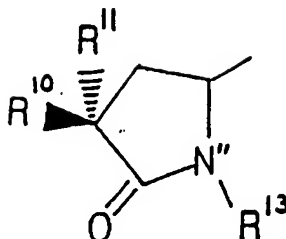
25 wherein, referring to formula (I), bond "a" is a single bond; bond "b" is a double bond; R¹² is -CH₂-R²⁸-, where R²⁸ is -N-; R¹³ is -C(R³³)-, where R³³ is COOH; and R¹⁴ is W-C''-R³⁷-, where R³⁷ is methylene, and W is C(R³⁸).

Other lactam moieties include the gamma-lactams of the representative formula:

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10 wherein, referring to formula (II), bond "a" is a single bond; bond "b" is nil; R¹² is -CH₂-R²⁸-, where R²⁸ is -C(R^{8a}) and R^{8a} is hydrogen; R¹³ is -SO₃H, -PO(OR³⁴)OH, -C(O)NHSO₂N(R³⁴)(R³⁵), -OSO₃H, -CH(R³⁵)COOH, or -OCH(R³⁴)COOH; and R¹⁴ is nil.

15 Preferred lactam-containing moieties include isocephems, iso-oxacephems, oxacephems, carbacephems, penicillins, penems, carbapenems, and monocyclic beta-lactams. More preferred are penems, carbapenems and monocyclic beta-lactams. Particularly preferred lactam-containing moieties for compounds made by this invention are penems.

20 R¹⁰, in formula (II), is any radical that may be substituted at the active stereoisomeric position of the carbon adjacent to the lactam carbonyl of an antimicrobially-active lactam. (As used herein, the term "antimicrobially-active lactam" refers to a lactam-containing compound, without a quinolonyl substituent moiety, which has antimicrobial activity.) This "active" position is beta (i.e., 7-beta) for oxacephems and carbacephems (for example). The active position is alpha for penems, carbapenems, clavams and clavams.

30 Appropriate R¹⁰ groups will be apparent to one of ordinary skill in the art. Many such R¹⁰ groups are known in the art, as described in the following documents (all of which are incorporated by reference herein): Cephalosporins and Penicillins: Chemistry and Biology (E. Flynn, editor, 1972); Chemistry and Biology of β -Lactam Antibiotics (R. Morin et al., editors, 1987); "The Cephalosporin Antibiotics: Seminar-in-Print", 34 Drugs (Supp. 2) 1 (J. Williams, editor,

- 1987); New Beta-Lactam Antibiotics; A Review from Chemistry of Clinical Efficacy of the New Cephalosporins (H. Neu, editor, 1982); M. Sassiver et al., in Structure Activity Relationships among the Semi-synthetic Antibiotics (D. Perlman, editor, 1977).
- 5 W. Durckheimer et al., "Recent Developments in the Field of Beta-Lactam Antibiotics", 24 Angew. Chem. Int. Ed. Engl. 180 (1985); G. Rolinson, "Beta-Lactam Antibiotics", 17 J. Antimicrobial Chemotherapy 5 (1986); European Patent Publication 187,456, Jung, published July 16, 1986; and World Patent
- 10 Publication 87/05297, Johnston et al., published September 11, 1987.

For penems, carbapenems, clavams and clavams, R¹⁰ is preferably lower alkyl, or hydroxy-substituted lower alkyl. Particularly preferred R¹⁰ groups include hydrogen,

15 hydroxymethyl, ethyl, [1(R)-hydroxyethyl], [1(R)-[(hydroxysulfonyl)oxyethyl]], and [1-methyl-1-hydroxyethyl].

Except for penems, carbapenems, clavams and clavams, preferred R¹⁰ groups are amides, such as: acetylamino, preferably substituted with aryl, heteroaryl, aryloxy,

20 heteroarylthio and lower alkylthio substituents; arylglycylamino, preferably N-substituted with heteroarylcarbonyl and cycloheteroalkylcarbonyl substituents; arylcarbonylamino; heteroarylcarbonylamino; and lower alkoxyiminoacetylamino, preferably substituted with aryl and heteroaryl substituents.

25 Particularly preferred R¹⁰ groups include amides of the general formula R¹⁸-(CH₂)_m-C(=O)NH- and R¹⁸ is R¹⁷. Examples of such preferred R¹⁰ groups include:

- [(2-amino-5-halo-4-thiazolyl)acetyl]amino;
[(4-aminopyridin-2-yl)acetyl]amino;
30 [[(3,5-dichloro-4-oxo-1(4H)-pyridinyl)acetyl]amino];
[[[2-(aminomethyl)phenyl]acetyl]amino];
[[1H-tetrazol-1-yl]acetyl]amino];
[(cyanoacetyl)amino];
[(2-thienyl)acetyl]amino];
35 [[(2-amino-4-thiazoyl)acetyl]amino]; and
sydnone, 3-[-2-amino]-2-oxoethyl.

When R¹⁰ is R¹⁸-(CH₂)_m-C(C=O)NH-, and R¹⁸ is -Y¹, preferred R¹⁰ groups include the following:

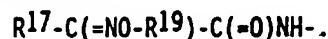
- [sulfamoylphenylacetyl]amino;
- [[[(4-pyridinylthio)acetyl]amino];
- 5 [[[(cyanomethyl)thio]acetyl]amino];
- (S)-[[[(2-amino-2-carboxyethyl)thio]acetyl]amino];
- [[[(trifluoromethyl)thio]acetyl]amino]; and
- (E)-[[[(2-aminocarbonyl-2-fluoroethenyl)thio]acetyl]amino].

10 When R¹⁰ is R¹⁸-(CH₂)_m-C(=O)NH-, and R¹⁸ is -CH(Y²)(R¹⁷), preferred R¹⁰ groups include the following:

- [carboxyphenylacetyl]amino;
- [(phenoxyacetyl)phenylacetyl]amino;
- [4-methyl-2,3-dioxo-1-piperazinecarbonyl-D-phenylglycyl]-
- 15 amino;
- [[[3-(2-furylmethyleneamino)-2-oxo-1-imidazolidinyl]-
- carbonyl]amino]phenyl]acetyl]amino;
- (R)-[(aminophenylacetyl]amino];
- (R)-[[amino(4-hydroxyphenyl)acetyl]amino];
- 20 (R)-[[amino(1,4-cyclohexadien-1-yl)acetyl]amino];
- [(hydroxyphenylacetyl]amino];
- (R)-[[[(4-ethyl-2,3-dioxo-1-piperazinyl)carbonyl]amino]-
- (4-hydroxyphenyl)acetyl]amino];
- (R)-[[[(5-carboxy-1H-imidazol-4-yl)carbonyl]amino]phenyl-
- 25 acetyl]amino];
- (R)-[[[(4-hydroxy-6-methyl-3-pyridinyl)carbonyl]amino](4-
- hydroxyphenyl)acetyl]amino];
- (R)-[(phenylsulfoacetyl]amino];
- (2R,3S)-[[2-[[[(4-ethyl-2,3-dioxo-1-piperazinyl)carbonyl]-
- 30 amino]-3-hydroxy-1-oxobutyl]amino];
- [[carboxy(4-hydroxyphenyl)acetyl]amino];
- (R)-[[amino[3-[(ethylsulfonyl)amino]phenyl]acetyl]amino];
- (R)-[[amino(benzo[b]thien-3-yl)acetyl]amino];
- (R)-[[amino(2-naphthyl)acetyl]amino];
- 35 (R)-[[amino(2-amino-4-thiazolyl)acetyl]amino];

- [[[(6,7-dihydroxy-4-oxo-4H-1-benzopyran-3-yl)carbonyl]-
 amino](4-hydroxyphenyl)acetyl]amino];
 (R,R)-[[2-[4-[2-amino-2-carboxyethyloxycarbonyl]aminophen-
 yl]-2-hydroxyacetyl]amino]; and
 5 (S)-[[[(5-hydroxy-4-oxo-1(4H)-pyridin-2-yl)carbonylamino(2-
 amino-4-thiazolyl)acetyl]amino].

Another preferred R^{10} group is $R^{17}-C(=CHR^{20})-C(=O)NH-$.
 Another class of preferred R^{10} groups (for lactam-containing
 10 moieties other than penems, carbapenems, clavams and clavams)
 include those of the formula:



Examples of this preferred class of R^{10} groups include:

- 2-phenyl-2-hydroxyiminoacetyl;
 15 2-thienyl-2-methoxyiminoacetyl; and
 2-[4-(gamma-D-glutamyl)oxy]phenyl]-2-hydroxyiminoacetyl.
 (Z)-[[[(2-amino-4-thiazolyl)(methoxyimino)acetyl]amino];
 [[[(2-furanyl)(methoxyimino)acetyl]amino];
 (Z)-[[[(2-amino-4-thiazolyl)[(1-carboxy-1-methyl)ethoxyim-
 20 ino]acetyl]amino];
 (Z)-[[[(2-amino-4-thiazolyl)(1-carboxymethoxyimino)acetyl]am-
 ino];
 [[[(2-amino-4-thiazolyl)[(1H-imidazol-4-ylmethoxy)imino]acet-
 yl]amino];
 25 (Z)-[[[(2-amino-4-thiazolyl-3-oxide)(methoxyimino)acetyl]am-
 ino]; and
 (S,Z)-[[[(2-amino-4-thiazolyl)[carboxy(3,4-dihydroxyphen-
 yl)methoxyimino]acetyl]amino].

- 30 Suitable R^{11} groups are among those well-known in the art,
 including those defined in the following documents (all
 incorporated by reference herein). W. Durckheimer et al.,
 "Recent Developments in the Field of Beta-Lactam Antibiotics",
 24 Angew. Chem. Int. Ed. Engl. 180 (1985); G. Rolinson,
 35 "Beta-Lactam Antibiotics", 17 J. Antimicrobial Chemotherapy 5
 (1986); and European Patent Publication 187,456, Jung, published

July 16, 1986. Preferred R¹¹ groups include hydrogen, methoxy, ethoxy, propoxy, thiomethyl, halogen, cyano, formyl and formylamino. Particularly preferred R¹¹ groups include hydrogen, methoxy, halogen, and formylamino.

5 Quinolone Moieties:

Groups A¹, A², A³, R¹, R³, and R⁴ of formula I form a moiety (herein, "quinolone moiety") present in any of a variety of quinolone, naphthyridine or related heterocyclic compounds known in the art to have antimicrobial activity. Such heterocyclic
10 moieties are well known in the art, as described in the following articles, all incorporated by reference herein: J. Wolfson et al., "The Fluoroquinolones: Structures, Mechanisms of Action and Resistance, and Spectra of Activity In Vitro", 28 Antimicrobial Agents and Chemotherapy 581 (1985); and T. Rosen et al., 31 J. Med. Chem. 1586 (1988); T. Rosen et al., 31 J. Med. Chem. 1598 (1988); G. Klopman et al., 31 Antimicrob. Agents Chemother. 1831 (1987); 31:1831-1840; J. P. Sanchez et al., 31 J. Med. Chem. 983 (1988); J. M. Domagala et al., 31 J. Med. Chem. 991 (1988); M. P. Wentland et al., in 20 Ann. Rep. Med. Chem. 145 (D. M. Bailey, editor, 1986); J. B. Cornett et al., in 21 Ann. Rep. Med. Chem. 139 (D. M. Bailey, editor, 1986); P. B. Fernandes et al., in 22 Ann. Rep. Med. Chem. 117 (D. M. Bailey, editor, 1987); R. Albrecht, 21 Prog. Drug Research 9 (1977); and P. B. Fernandes et al., in 23 Ann. Rep. Med. Chem. (R. C. Allen, editor, 1987).

25 Preferred quinolone moieties include those where A¹ is C(R⁷), A² is C(R²), and A³ is C(R⁵) (i.e., quinolones); A¹ is nitrogen, A² is C(R²), and A³ is C(R⁵) (i.e., naphthyridines); A¹ is C(R⁷), A² is C(R²), and A³ is nitrogen (i.e., cinnoline acid derivatives); and where A¹ is nitrogen, A² is nitrogen, and A³ is C(R⁵) (i.e., pyridopyrimidine derivatives). More preferred
30 quinolone moieties are those where A¹ is C(R⁷), A² is C(R²), and A³ is C(R⁵) (i.e., quinolones); and where A¹ is nitrogen, A² is C(R²), and A³ is C(R⁵) (i.e., naphthyridines). Particularly preferred quinolone moieties are where A¹ is C(R⁷), A² is C(R²),
35 and A³ is C(R⁵) (i.e., quinolones).

R¹ is preferably alkyl, aryl, cycloalkyl and alkylamino. More preferably, R¹ is ethyl, 2-fluoroethyl, 2-hydroxyethyl, t-butyl, 4-fluorophenyl, 2,4-difluorophenyl, methylamino and cyclopropyl. Cyclopropyl is a particularly preferred R¹ group.
5 Preferred quinolone moieties also include those where A¹ is C(R⁷) and R¹ and R⁷ together comprise a 6-membered heterocyclic ring containing an oxygen or sulfur atom.

R² is preferably hydrogen or halo. More preferably R² is chlorine or fluorine. Fluorine is a particularly preferred R²
10 group.

Preferred R³ groups include nitrogen-containing heterocyclic rings. Particularly preferred are nitrogen-containing heterocyclic rings having from 5 to 8 members. The heterocyclic ring may contain additional heteroatoms, such as oxygen, sulfur,
15 or nitrogen, preferably nitrogen. Such heterocyclic groups are described in U.S. Patent 4,599,334, Petersen et al., issued July 8, 1986; and U.S. Patent 4,670,444, Grohe et al., issued June 2, 1987 (both incorporated by reference herein). Preferred R³ groups include unsubstituted or substituted pyridine, piperidine, morpholine, diazabicyclo[3.1.1]heptane, diazabicyclo[2.2.1]heptane, diazabicyclo[3.2.1]octane, diazabicyclo[2.2.2]octane, thiazolidine, imidazolidine, pyrrole and thiamorpholine, as well as the following particularly preferred R³ groups include
20 piperazine, 3-methylpiperazine, 3-aminopyrrolidine, 3-aminomethylpyrrolidine, N,N-dimethylaminomethylpyrrolidine, N-methylaminomethylpyrrolidine, N-ethylaminomethylpyrrolidine, pyridine, N-methylpiperazine, and 3,5-dimethylpiperazine.

The specific physical, chemical, and pharmacological properties of the quinolonyl lactams of this invention may depend
30 upon the particular combination of the integral lactam-containing moiety, quinolone moiety and linking moiety comprising the compound. For example, selection of particular integral moieties may affect the relative susceptibility of the quinolonyl lactam to bacterial resistance mechanisms (e.g., beta-lactamase
35 activity).

Preferred lactam moieties, quinolone moieties, and QLAs are described in the following documents, all of which are incorporated by reference herein: European Patent Publication 366,189, White and Demuth, published May 2, 1990; European Patent
5 Publication 335, 297, Albrecht et al., published October 4, 1989; and U.S. Patent Application Serial No. 07/511,483, Demuth and White, filed April 18, 1990.

Methods of Manufacture

10 The processes of this invention comprise the steps of:

- (1) Reacting a lactam compound of the formula B-L⁴-H with phosgene to form an intermediate compound of the formula B-L⁴-C(=O)-Cl; and
- (2) Coupling said intermediate compound with a quinolone
15 compound of the formula Q-L³-R⁴⁴; wherein R⁴⁴ is hydrogen, Si(R⁴⁵)₃, or Sn(R⁴⁵)₃; and R⁴⁵ is lower alkyl.

Preferably, these processes additionally comprise steps for protecting the lactam and quinolone compounds prior to the reacting and coupling steps. In particular, the carboxylate
20 groups at R⁴ and R¹³ are protected, using an ester group. The compound formed following the coupling step is then deprotected, by removal of the ester groups, to yield the free acid compound.

Accordingly, a preferred process of this invention additionally comprises:

- 25 (a) a step, prior to said reacting step, wherein an ester of said lactam compound is formed;
- (b) a step, prior to said coupling step, wherein an ester of said quinolone compound is formed; and
- (b) deprotection steps, after said coupling step, wherein
30 said groups are removed.

Suitable hydrolyzable esters useful in such protection steps are well known in the art. They include, for example, allyl, benzyl, p-methoxybenzyl, p-nitrobenzyl, diphenylmethyl, methyl, ethyl, 2,2,2-trichloroethyl, 2-trimethylsilyl ethyl, 2-methylthioethyl,
35 trimethylsilyl, t-butyl diphenylsilyl, t-butyl, and tributylstannyl esters. Such esters, and suitable protection and

deprotection chemistry for carboxylates and other functional groups, are described in T. W. Greene, Protective Groups in Organic Synthesis, J. Wiley and Sons (1981), incorporated by reference herein.

5 Further, depending on the specific lactam compounds and quinolone compounds employed, other functional groups (e.g., the R¹⁰ substituent or the lactam compound) may need to be protected or blocked in order to prevent undesired competing side reactions from occurring during the coupling step. Protecting groups for
10 hydroxyl substituents include ethers, esters, and carbonates; and protecting groups for amino substituents include carbamates, and amides. If various protecting groups are employed, then an appropriate deprotecting step, that will not decompose the coupled conjugate, may be required to obtain antibacterially
15 active products. Chemistry useful in the protecting and deprotecting steps are well known in the chemical literature.

In a preferred process, a silylated quinolone compound is used in the coupling step, wherein R⁴⁴ of the quinolone compound is Si(R⁴⁵)₃, and R⁴⁵ is lower alkyl. Preferably R⁴⁵ is methyl or
20 ethyl. Also, the R⁴⁵ groups may be independently selected, such that the Si(R⁴⁵)₃ moiety need not contain three identical R⁴⁵ substituents.

Any of a number of silylating reagents known in the art may be used to form the silylated quinolone compound, by reacting the
25 silylating agent with a quinolone compound wherein R⁴⁴ is hydrogen. Such silylating reagents include, for example, chlorotrimethylsilane; N-methyl-N-trimethylsilyl-trifluoroacetamide; N,N-bis(trimethylsilyl)urea; 1-trimethylsilylimidazole; bis(trimethylsilyl)trifluoroacetamide; and
30 N,O-bis(trimethylsilyl)acetamide. Further, use of the silylating agent to form a silylated quinolone compound may also yield a silyl ester of R⁴ carboxylate of the quinolone, as a protecting group. This ester can then be removed, using well-known deprotection chemistry.

35 The reacting step and coupling step are carried out in solution, using any of a variety of suitable solvents. Such

solvents include, for example: halocarbon solvents, such as methylene chloride, chloroform, and dichloroethane; ethers, such as diethyl ether and tetrahydrofuran (THF); aromatic solvents, such as benzene and toluene; and mixtures thereof. Halocarbon solvents are preferred. Preferably the coupling step comprises adding a solution containing the quinolone compound to a solution containing the intermediate compound.

The reacting step and coupling step are preferably conducted at low temperatures, from -92° C to about 22° C. Preferably the temperatures are from about -80° C to about 0° C, more preferably from about -80° C to about -40° C. Preferably, reagents are mixed in the reaction step and coupling step so as to allow control of the temperature within these ranges.

Procedures for making a broad variety of lactam and quinolone starting materials are well known in the art. For example, procedures for preparing lactam-containing moieties are described in the following references, all incorporated by reference herein (including articles cited within these references): Cephalosporins and Penicillins: Chemistry and Biology (E. H. Flynn, ed, 1972) Chapters 2, 3, 4, 5, 6, 7, 15 and Appendix I; Recent Advances in the Chemistry of β -Lactam Antibiotics (A.G. Brown and S. M. Roberts, ed., 1985); Topics in Antibiotic Chemistry, Vol. 3, (Part B) and Vol. 4, (P. Sommes, ed., 1980); Recent Advances in the Chemistry of β -lactam Antibiotics (J. Elks, ed., 1976); Structure-Activity Relationships Among the Semisynthetic Antibiotics (D. Perlman, ed, 1977); Chaps. 1, 2, 3, 4; Antibiotics, Chemotherapeutics and Antibacterial Agents for Disease Control (M. Grayson, ed, 1982); Chemistry and Biology of β -Lactam Antibiotics, Vols 1-3 (K. B. Morin and M. Gorman, eds, 1982); 4 Medicinal Research Reviews 1-24 (1984); 8 Medicinal Research Review 393-440 (1988); 24 Angew. Chem. Int. Ed. Engl. 180-202 (1985); 40 J. Antibiotics 182-189 (1987); European Patent Publication 266,060; 42 J. Antibiotics 993 (1989); U.S. Patent 4,742,053; 35 Chem. Pharm. Bull. 1903-1909 (1987); 32 J. Med. Chem., 601-604 (1989); U.S. Patent 4,791,106; Japanese Patent Publication 62/158291; 31 J.

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20 Application 053,815; 40 J. Antibiotics, 1563-1571 (1987); 40 J.
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 (1981); U.S. Patent 4,777,252; U.S. Patent 4,762,922; European
 Patent Publication 287,734; U.S. Patent 4,762,827; European
 Patent Publication 282,895; European Patent Publication 282,365;
 and U.S. Patent 4,777,673.

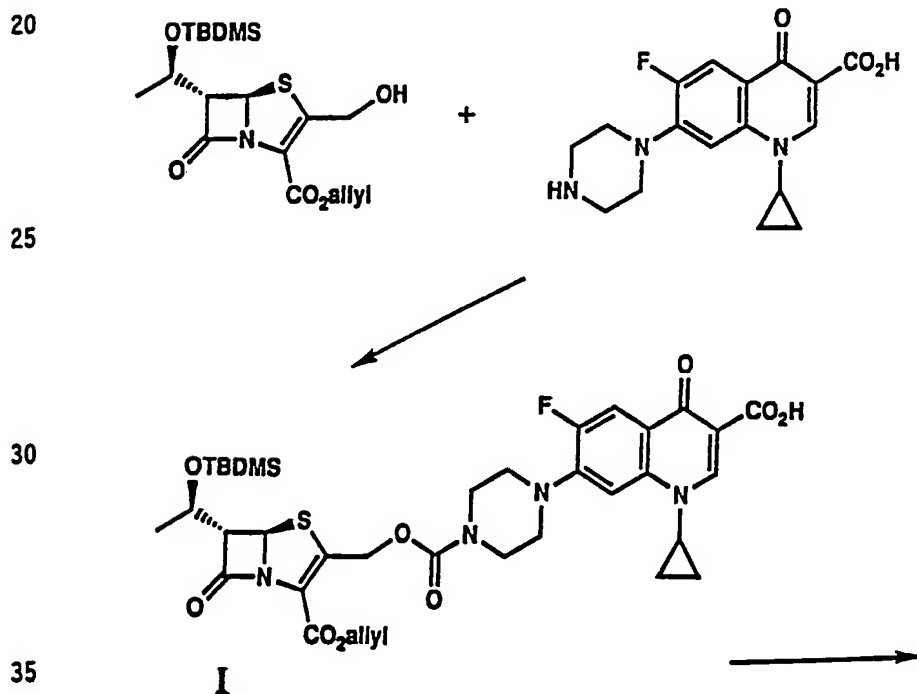
 General procedures for preparing quinolone compounds useful
 in the methods of this invention are described in the following
 references, all incorporated by reference herein (including
 articles listed within these references); 21 Progress in Drug
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 Pharm. Sci., 585-588 (1989); 26 J. Het. Chem., (1989); 24 J. Het.
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 J. Med. Chem., 991-1001 (1988); 25 J. Het. Chem., 479-485 (1988);
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35 Publication 227,088; European Patent Publication 227,039;
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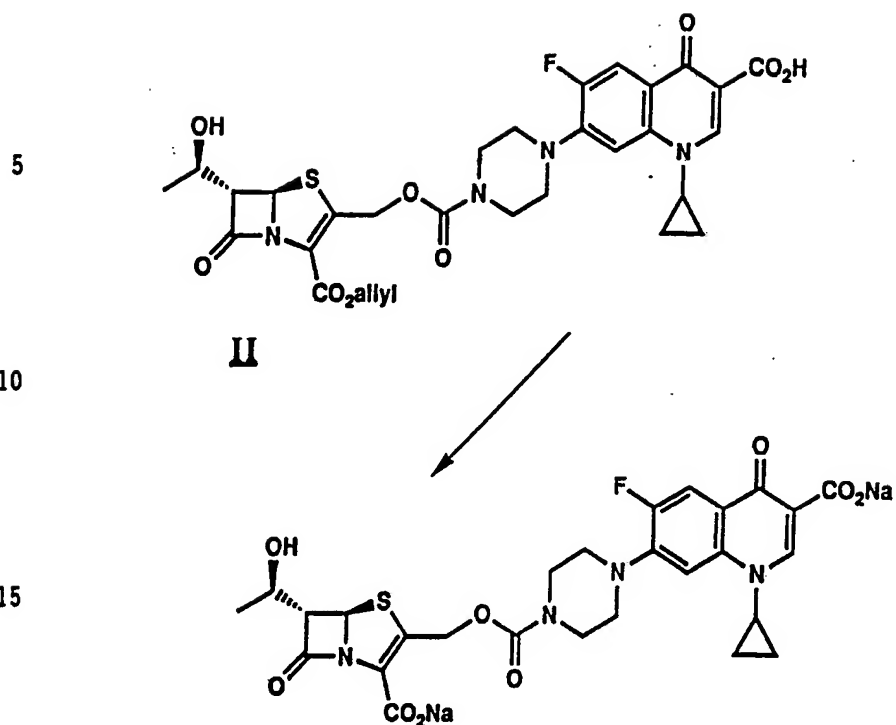
(1988); 31 J. Med. Chem., 1598-1611 (1988); and 23 J. Med. Chem., 1358-1363 (1980). Preparation of quinolone compounds useful herein are also described in: European Patent Publication 366,189, White and Demuth, published May 2, 1990; European Patent Publication 335, 297, Albrecht et al., published October 4, 1989; and U.S. Patent Application Serial No. 07/511,483, Demuth and White, filed April 18, 1990; incorporated by reference herein.

The following non-limiting examples illustrate the processes of the present invention.

EXAMPLE 1

Preparation of [5R-[5a,6a]]-3-[[[4-(3-Carboxy-1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-quinoliny)]-1-piperazinyl] carbonyloxy]methyl]-6-[(R)-1-hydroxyethyl]-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid Disodium Salt





A 3-neck, 1 L flask is fitted with a low temperature thermometer, overhead stirrer and a 500 mL dropping funnel. The apparatus is dried and then cooled to approximately -78° C under nitrogen with a dry ice/acetone bath. Phosgene (60 mL, 20% in toluene) is added via syringe through the dropping funnel. Dichloromethane is then rinsed through the dropping funnel into the flask. A solution of [5R-[5a,6a]]-6-[(R)-1-(t-butyltrimethylsilyl-oxy)ethyl]-3-hydroxymethyl-7-oxo-4-thia-1-azabicyclo [3.2.0]hept-2-ene-2-carboxylic acid allyl ester (40 gram) and N,N-diisopropylethylamine (20 mL) in 150 mL dichloromethane is transferred via cannula to the dropping funnel on the 1 L flask. This solution is then added to the phosgene solution at such a rate as to maintain the solution temperature between -75° C and -70° C (approximately 2.5 hour). Separately, N-methyl-N-trimethylsilyl-trifluoroacetamide (56 mL) is added to a suspension of 1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinoline carboxylic acid (33.2 gram) in 250 mL

dichloromethane at room temperature. The resulting solution is transferred to the dropping funnel on the 1 L flask via cannula and is added to the reaction mixture at such a rate so as to maintain the reaction temperature between -75° C and -70° C over approximately 1.5 hour. The reaction mixture is stirred for approximately 15 minutes, the cooling bath is removed and 50 mL of water is added, allowing the solution to warm to approximately -10° C. A second aliquot of water (50 mL) is added and the mixture is further warmed to 10° C.

The solution is filtered, extracted with water, washed with brine, dried over sodium sulfate and concentrated to approximately 200 mL volume in vacuo. With overhead stirring, methanol (approximately 400 mL) is added to the resulting solution causing an immediate precipitation of an off-white solid. After stirring 15 minutes, the solid is filtered, washed with methanol, then ether and dried under high vacuum to yield approximately 57 gram product I.

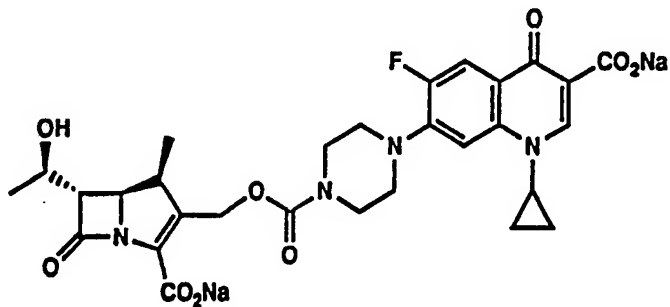
To a mixture of product I (26 gram) in 360 mL THF containing 19 mL acetic acid at room temperature is rapidly added a solution of tetrabutylammonium fluoride hydrate (32 gram) in 640 mL THF. The reaction is stirred for 24 hours and concentrated to dryness in vacuo. The residue is dissolved in dichloromethane (400 mL), extracted twice with water, washed with brine, dried over sodium sulfate, filtered and concentrated to approximately 250 mL. The solution is diluted with an equal volume of diethyl ether to precipitate the product which is collected by filtration and air-dried to yield approximately 18 gram of product II.

To a solution of II (5.2 gram) in 500 mL dichloromethane at 0° C is added 0.76 mL water and bis(triphenylphosphine)palladium (II) chloride (0.13 gram) followed by the rapid addition of tributyltin hydride (2.8 mL). The solution is stirred for 35 minutes at 0° C, then cooled to -7° C to -10° C. Sodium 2-ethylhexanoate (2.6 gram) in 250 mL THF is then added dropwise over 30 minutes. The mixture is stirred an additional 15 minutes and the precipitated product is collected by filtration. The crude solid is stirred in 60 mL acetone for one hour, collected

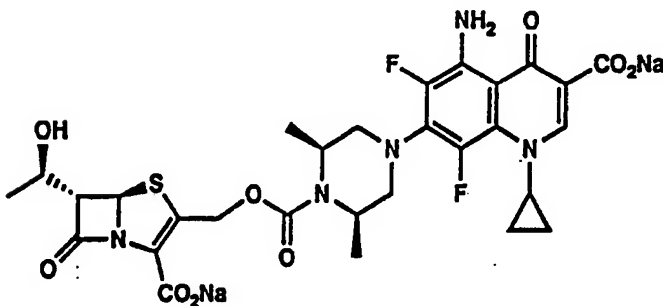
by centrifugation and dried in vacuo to yield 5 gram of the title compound.

The following QLAs are also prepared, according to the procedure of the above Example, with substantially similar results.

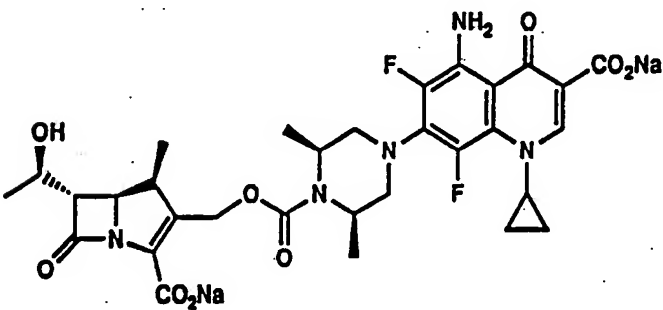
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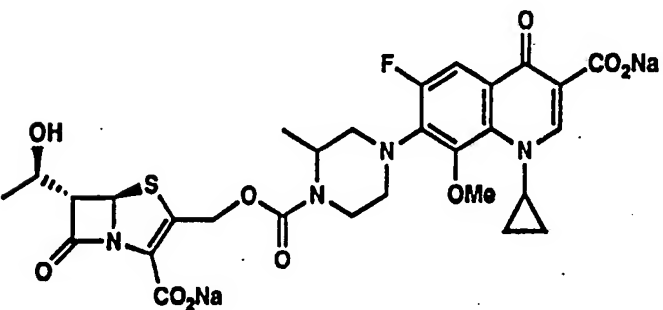


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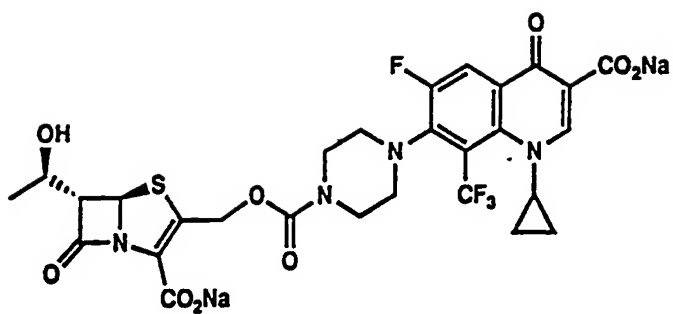
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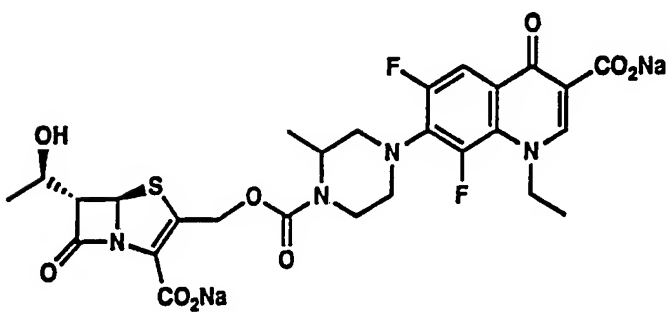


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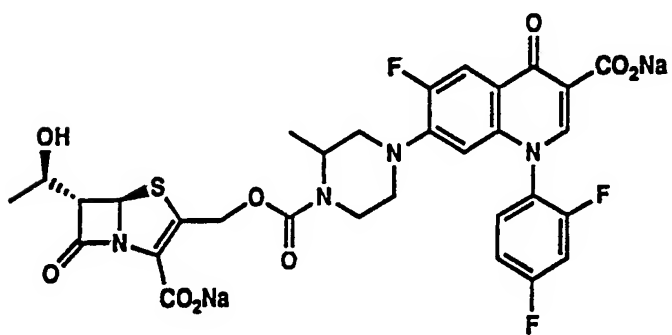


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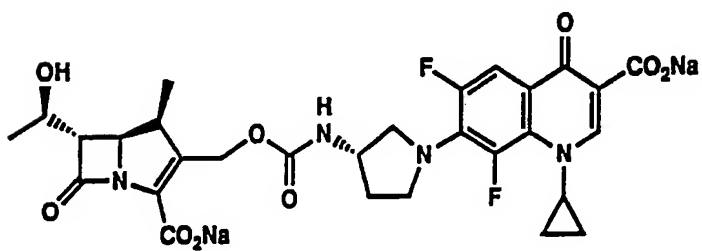
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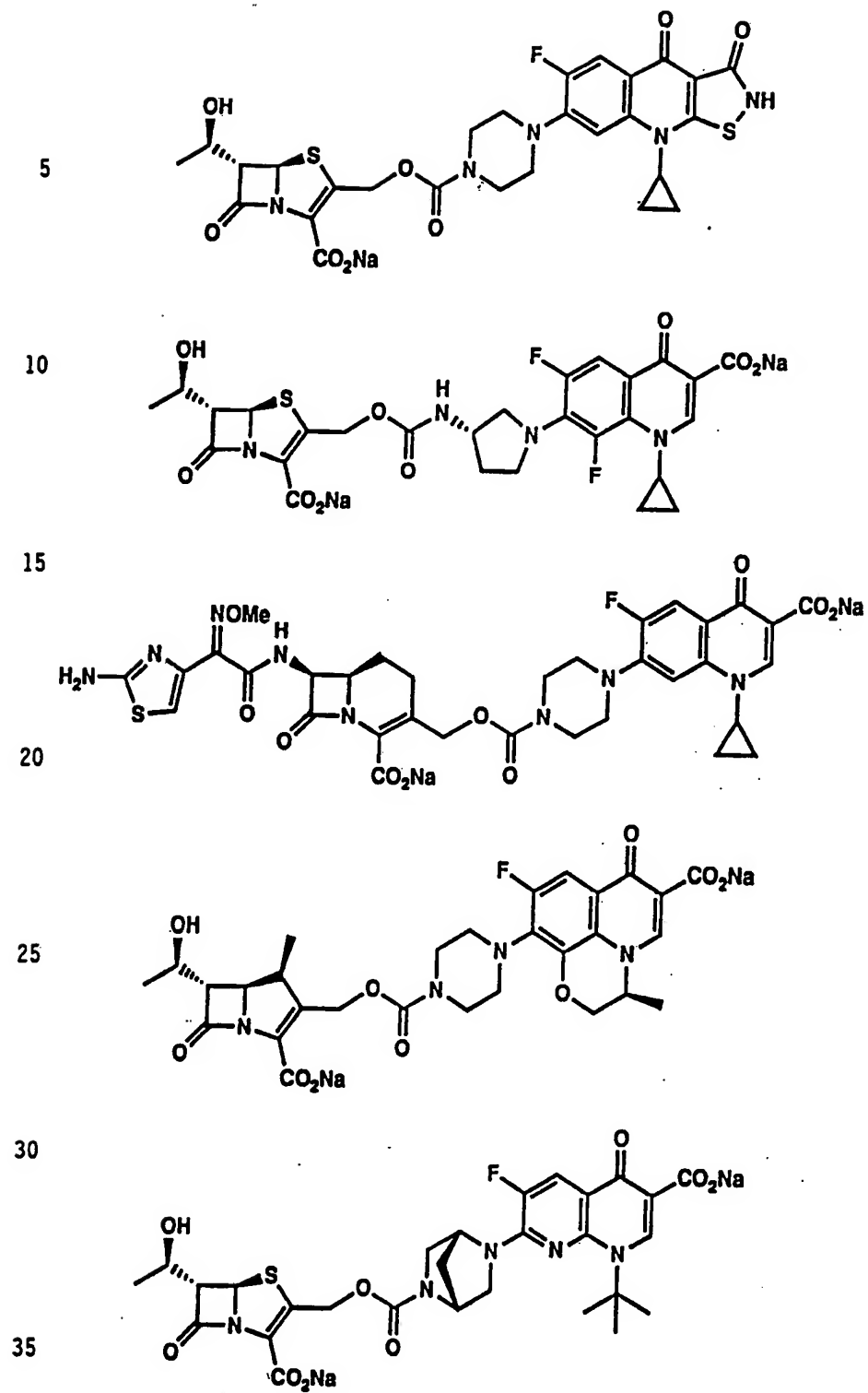


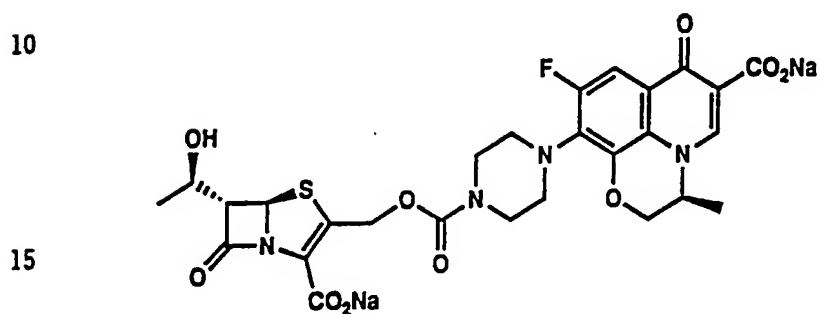
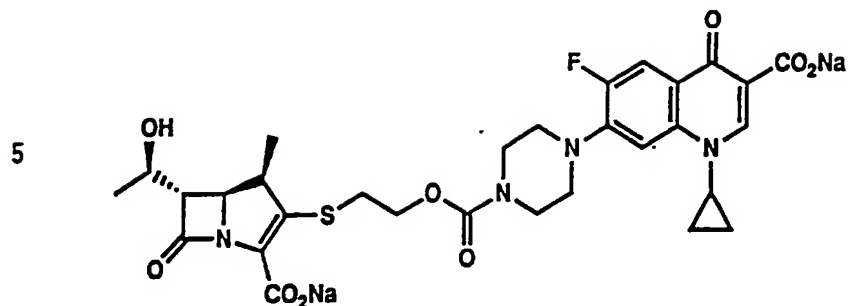
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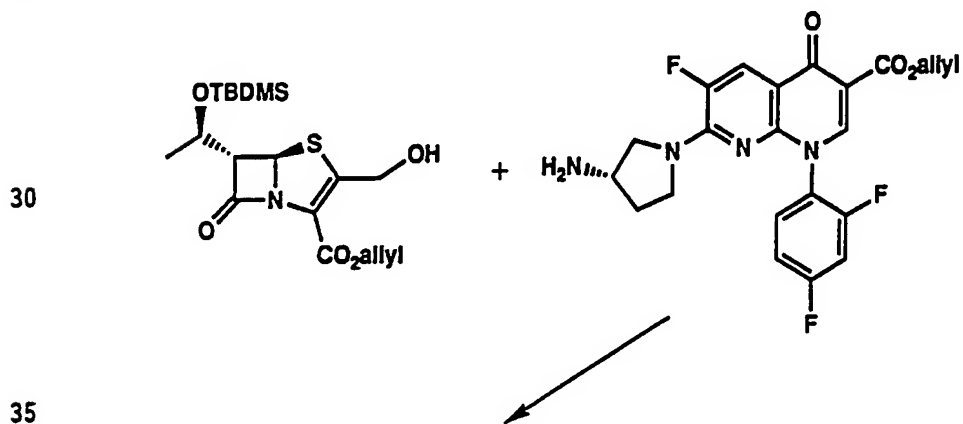
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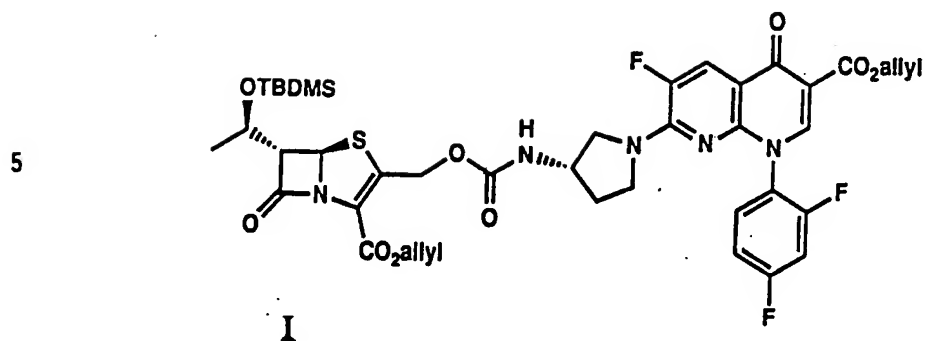


**EXAMPLE 2**

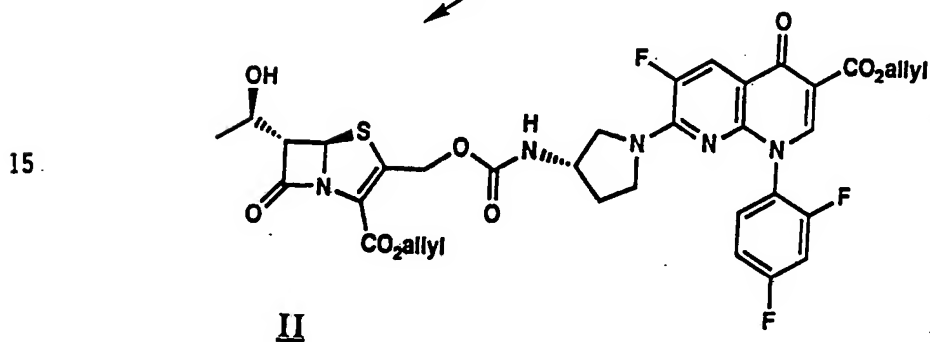
20 Preparation of [5R-[5a,6a]]-[3-[[[1-(3-Carboxy-1-(3,4-difluorophenyl)-6-fluoro-1,4-dihydro-4-oxo-1,8-naphthyridin-7-yl)-pyrrolidin-3-yl]amino]carbonyloxy]methyl]-6-[(R)-1-hydroxyethyl]-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid Disodium Salt

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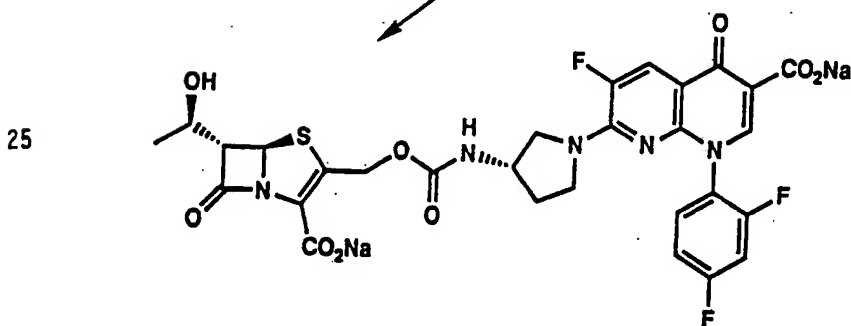




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To a solution of 20% phosgene in toluene (1.3 mL) in 11 mL dichloromethane with diisopropylethylamine (0.48 mL) at -35° C to -45° C under a nitrogen atmosphere is added dropwise a solution of [5R-[4b,5a,6a]]-6-[(R)-1-(t-butyldimethylsilyl-oxy)ethyl]-3-hydroxymethyl-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid allyl ester (1.0 gram) in 11 mL dichloromethane.

35

The reaction is stirred 1 hour at -35° C to -45° C, then cooled to -78° C. A chilled (-40° C) solution of the 7-(3-aminopyrrolidin-1-yl)-1-(2,4-difluorophenyl)-6-fluoro-1,4-dihydro-4-oxo-1,8-naphthyridine-3-carboxylic acid allyl ester (1.1 gram) with
5 diisopropylethylamine (0.48 mL) in 23 mL dichloromethane is added by cannula while maintaining the solution temperature below -70° C. After 30 min. the reaction mixture is extracted with cold 0.1 N HCl and water. The dichloromethane layer is dried over sodium sulfate and the solvent evaporated under vacuum. The
10 residue was triturated with hexanes to yield approximately 1.8 gram of product I.

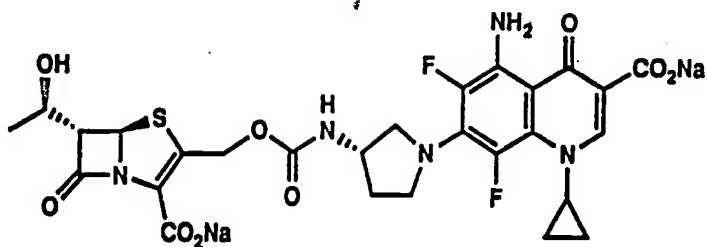
To a room temperature solution of product I (2.2 gram) in 40 mL of THF with 1.4 mL of acetic acid is added tetrabutylammonium fluoride hydrate (2.3 gram) in 17 mL of THF dropwise. The
15 mixture is stirred for 24 hours at room temperature under nitrogen atmosphere. The solvent is evaporated under vacuum, the residue is taken up in 50 mL dichloromethane and is washed with water and brine. The dichloromethane layer is dried over sodium sulfate and evaporated in vacuo. The residue is triturated with
20 hexanes and the solid filtered, ground by mortar and pestle in ether, and then further triturated with ether. The solid is filtered to yield 0.80 gram of product II.

To a solution of product II (0.5 gram) in 40 mL of dichloromethane with bis(triphenylphosphine) palladium(II) chloride (0.019 gram) and 0.060 mL of water at 0° C under a
25 nitrogen atmosphere is added tributyltin hydride (0.46 mL) and the mixture allowed to stir for 30 min. Sodium 2-ethylhexanoate (0.22 gram) in 9.5 mL of THF is added to the above mixture at 0° C very slowly over 20 min. and stirred for an additional 15
30 min. after the addition is completed. The precipitate is filtered and washed with ether and acetone. The solid is ground by mortar and pestle with acetone and further triturated with acetone. The solid is filtered and triturated with a 1:12 mixture of aqueous isopropanol. The solid is filtered to yield
35 0.22 gram the title compound.

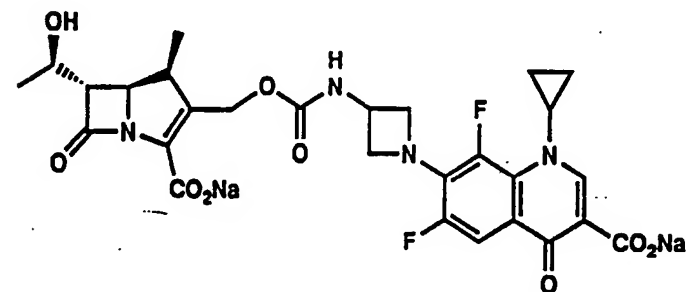
The following QLAs are also prepared, according to the procedure of the above Example, with substantially similar results.

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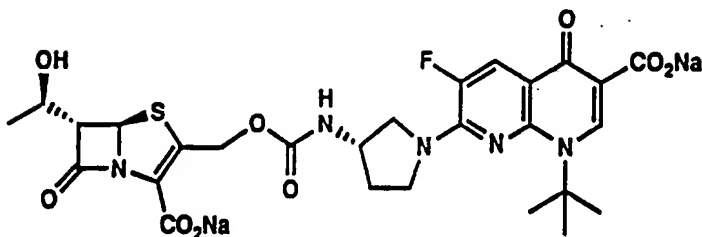
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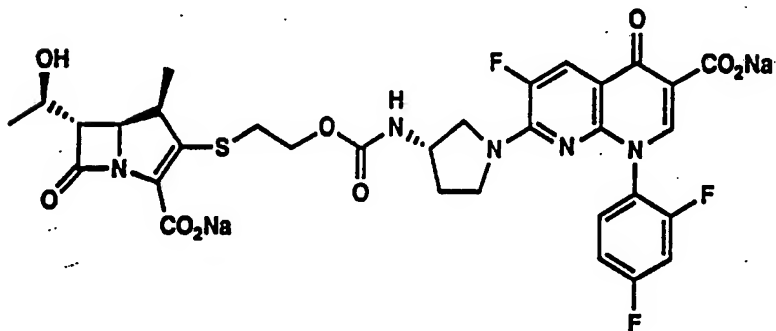


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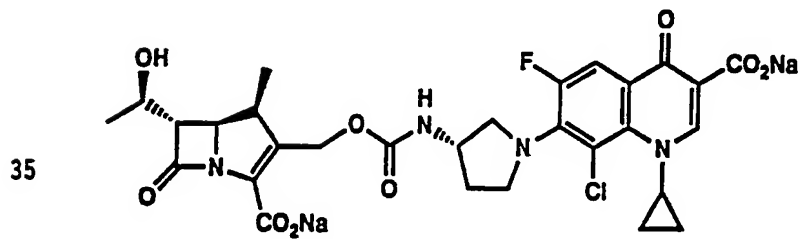
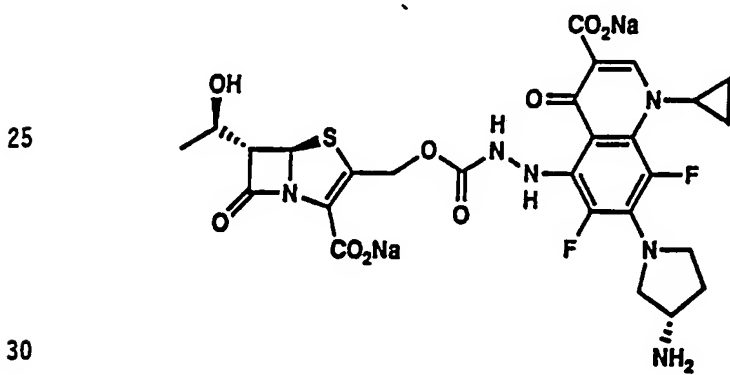
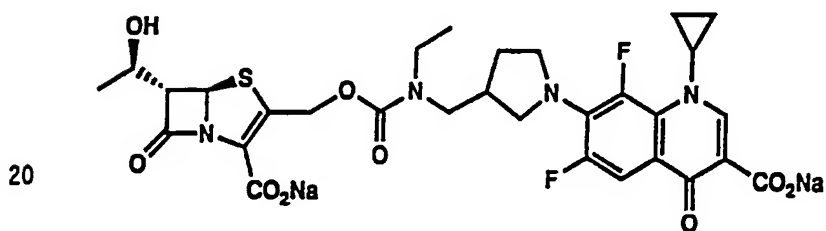
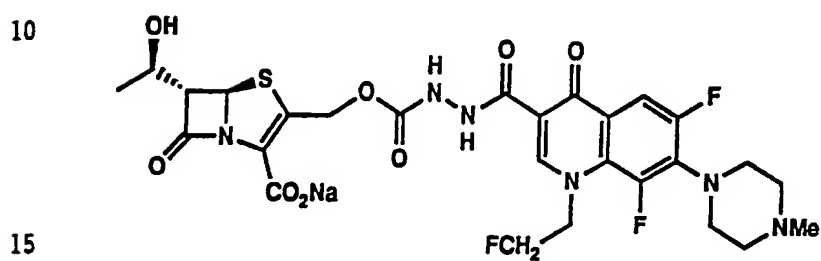
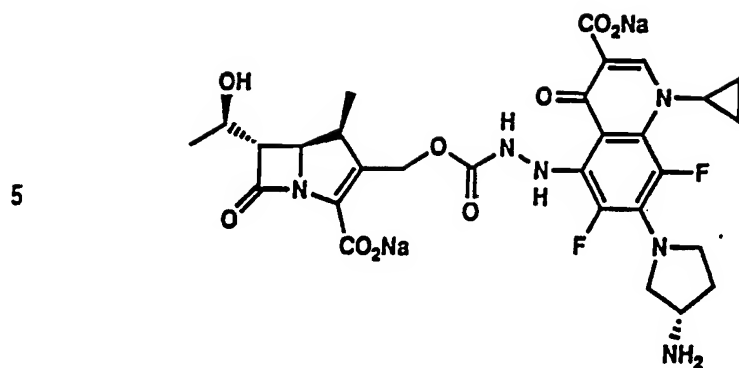


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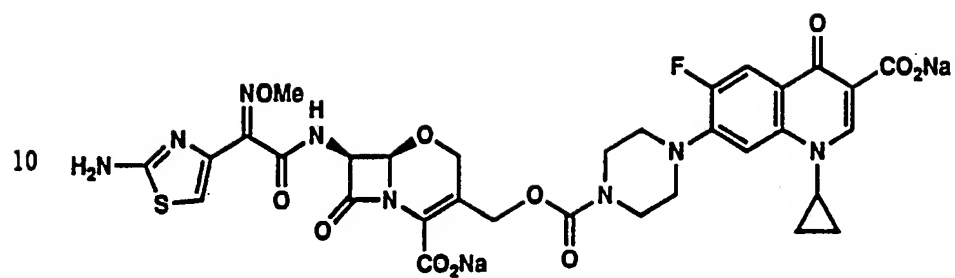
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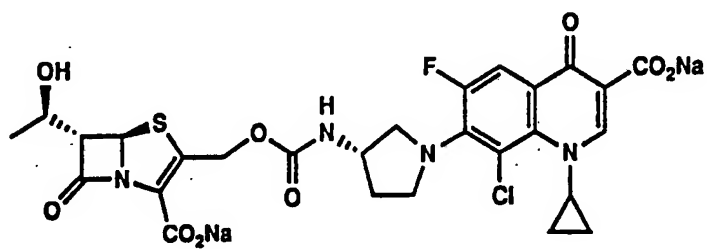
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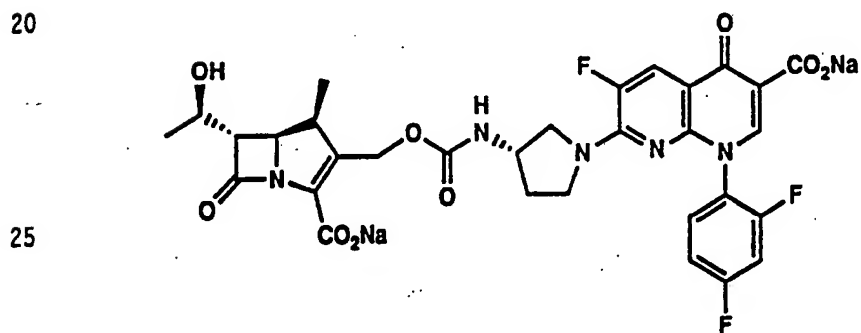
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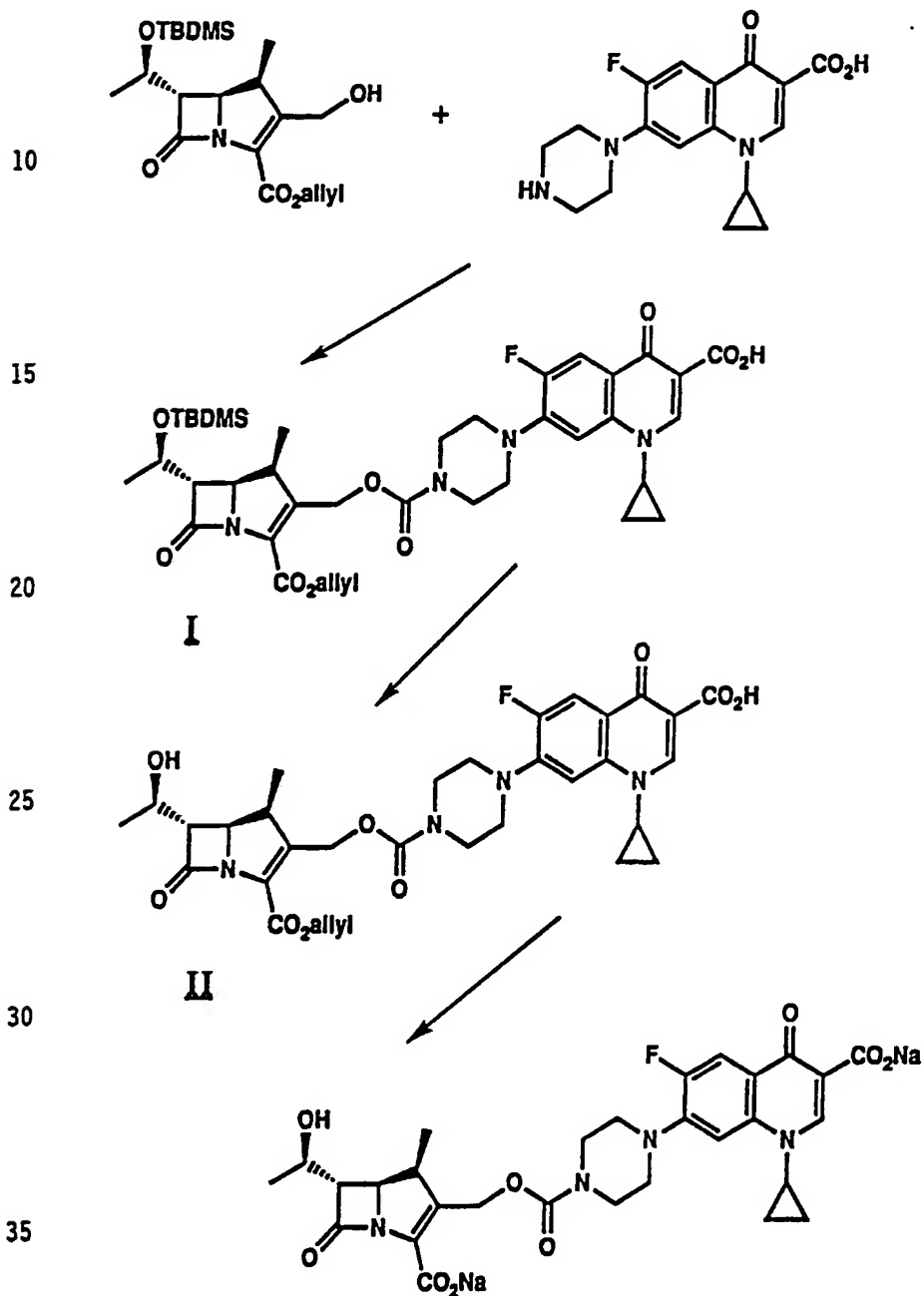


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EXAMPLE 3

Preparation of [5R-[4b,5a,6a]]-3-[[[4-(3-Carboxy-1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-quinoliny)]-6-[(R)-1-hydroxyoxyethyl]-1-piperazinyl]carbonyloxy]methyl]-4-methyl-7-oxo-1-azabicyclo
5 [3.2.0]hept-2-ene-2-carboxylic Acid Disodium Salt



A 30 L reactor is fitted with a low temperature thermometer, overhead stirrer is charged with dichloromethane (6 L) and toluene (1.8 L) and cooled to -78° C (internal temperature). Phosgene gas is introduced keeping the temperature below approximately -60° C. After recooling the mixture to -78° C, a solution of [5R-[4b,5a,6a]]-6-[(R)-1-(t-butyl dimethylsilyloxy)ethyl]-3-hydroxymethyl-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid allyl ester (1.2 kg) and N,N-diisopropylethylamine (580 mL) in 4.5 L dichloromethane is added to the reaction via metering pump at such a rate as to maintain the solution temperature between -75° C and -70° C. A premixed solution of N-methyl-N-trimethylsilyl-trifluoroacetamide (1.7 L) and 1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-(1-piperazinyl)-3-quinoline carboxylic acid (1 kg) in 7.5 L dichloromethane is then added to the reaction mixture at such a rate as to maintain the reaction temperature between -75° C and -70° C. The reaction mixture is stirred for approximately 15 minutes and 1.5 L of water is added, allowing the solution to warm to approximately -10° C. A second aliquot of water (1.5 L) is added and the mixture is further warmed to approximately 10° C. The solution is filtered, extracted with water, washed with brine, dried over sodium sulfate and concentrated to approximately 6 L volume. With overhead stirring, methanol (3.2 L) is added to the resulting solution causing an immediate off-white precipitate. After stirring 15 minutes, the solid is filtered, washed with methanol, then ether and dried to yield approximately 2.1 kg product I.

A 30 L reactor is charged with THF (5.3 L), tetrabutylammonium fluoride (3.22 L, 1 M in THF) and acetic acid (790 mL). Solid product I (870 gram) is added at room temperature with overhead stirring and the resulting suspension is stirred under nitrogen for 20-24 hours. The reaction mixture becomes homogenous overnight. Water (20 L) is added to the reactor, the resulting suspension stirred for one hour, and then the product is filtered. The crude product is placed into the 30 L reactor, more water (20 L) is added, the suspension is stirred for 1 h,

and then the product is refiltered, washed with THF (5 L), and then dried to give approximately 550 gram of product II.

5 A 30 L reactor equipped with an overhead stirrer is charged with product II (200 gram) and dichloromethane (12 L). The flask is purged with nitrogen and tetrakis(triphenyl-phosphine)palladium(0) (18 g) is added. The reaction mixture is cooled to -5° C and a solution of sodium 2-ethylhexanoate (103 g) in THF (6 L) is slowly added to the reaction vessel via a metering pump at such a rate that the internal temperature was maintained between -5° C to 0° C. Stirring of the reaction mixture is continued at -5° C for another 1.5 hour after completion of addition. The reaction mixture is then centrifuged, the supernatant decanted off, and the product washed with additional dichloromethane (6 L). Following centrifugation and decantation, the product is then washed with additional dichloromethane (6 L). This process of washing, centrifugation, and decantation is repeated twice more. Following the final decantation step, final drying of the product affords 180 grams of the title compound.

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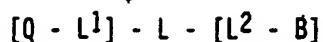
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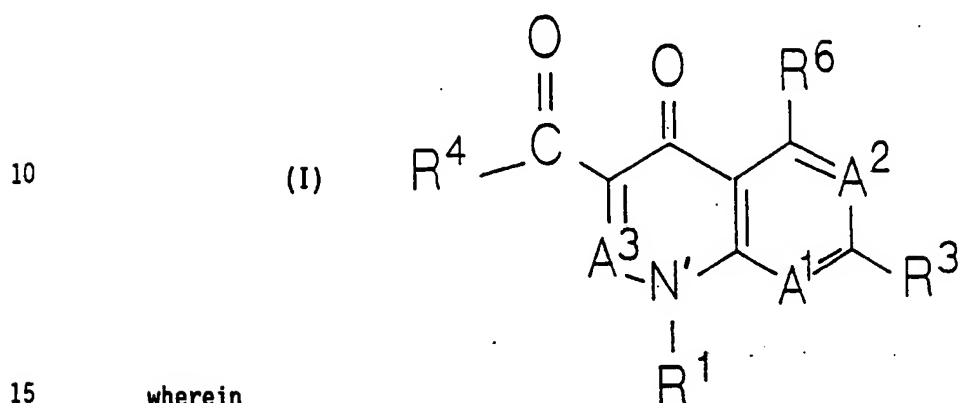
WHAT IS CLAIMED IS:

1. A process for making an antimicrobial compound of the formula



wherein

- 5 (I) - Q is a structure according to Formula (I)



wherein

- 20 (A) (1) A^1 is N or C(R^7); where
- (i) R^7 is hydrogen, hydroxy, alkoxy, nitro, cyano, halogen, alkyl, or N(R^8)(R^9), and
 - (ii) R^8 and R^9 are, independently, R^{8a} where R^{8a} is hydrogen, alkyl, alkenyl, carbocyclic ring, or heterocyclic ring; or R^8 and R^9 together comprise a heterocyclic ring including the nitrogen to which they are bonded;
- 25 (2) A^2 is N or C(R^2); where R^2 is hydrogen or halogen;
- (3) A^3 is N or C(R^5); where R^5 is hydrogen;
- (4) R^1 is hydrogen, alkyl, a carbocyclic ring, a heterocyclic ring, alkoxy, hydroxy, alkenyl, arylalkyl, or N(R^8)(R^9);
- 30 (5) R^3 is hydrogen, halogen, alkyl, a carbocyclic ring, or a heterocyclic ring;

(6) R^4 is hydroxy; and

(7) R^6 is hydrogen, halogen, nitro or $N(R^8)(R^9)$;

35 (B) except that

(1) when A^1 is $C(R^7)$, R^1 and R^7 may together comprise a heterocyclic ring including N' and A^1 ;

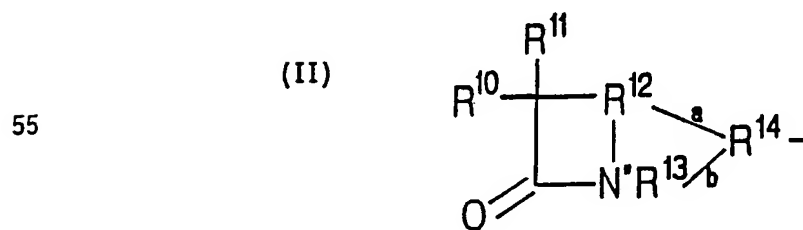
40 (2) when A^2 is $C(R^2)$, R^2 and R^3 may together comprise $-O-(CH_2)_n-O-$, where n is an integer from 1 to 4;

45 (3) when A^3 is $C(R^5)$, R^4 and R^5 may together comprise a heterocyclic ring including the carbon atoms to which R^4 and R^5 are bonded and the carbon atom of Formula (I) to which said carbon atoms are bonded; and

(4) when A^3 is $C(R^5)$, R^1 and R^5 may together comprise a heterocyclic ring including N' and the adjacent carbon to which R^5 is bonded;

50 (C) and except that one of R^1 , R^6 , or R^7 must be nil;

(II) B is a structure according to Formula (II):



60 wherein

(A) R^{10} is hydrogen, halogen, alkyl, alkenyl, heteroalkyl, a carbocyclic ring, a heterocyclic ring, $R^{8a}-O-$, $R^{8a}CH=N-$, $(R^8)(R^9)N-$, $R^{17}-C(=CHR^{20})-C(=O)NH-$, $R^{17}-C(=NO-R^{19})-C(=O)NH-$, or $R^{18}-(CH_2)_m-C(=O)NH-$; where

65 (1) m is an integer from 0 to 9;

- 70 (2) R¹⁷ is hydrogen, alkyl, alkenyl, heteroalkyl, heteroalkenyl, a carbocyclic ring, or a heterocyclic ring;
- (3) R¹⁸ is R¹⁷, -Y¹, or -CH(Y²)(R¹⁷);
- 75 (4) R¹⁹ is R¹⁷, arylalkyl, heteroarylalkyl, -C(R²²)(R²³)COOH, -C(=O)O-R¹⁷, or -C(=O)NH-R¹⁷, where R²² and R²³ are, independently, R¹⁷ or together comprise a carbocyclic ring or a heterocyclic ring including the carbon atom to which R²² and R²³ are bonded;
- (5) R²⁰ is R¹⁹, halogen, -Y¹, or -CH(Y²)(R¹⁷);
- 80 (6) Y¹ is -C(=O)OR²¹, -C(=O)R²¹, -N(R²⁴)R²¹, -S(O)_pR²⁹, or -OR²⁹; and Y² is Y¹ or -OH, -SH, or -SO₃H;
- (a) p is an integer from 0 to 2;
- (b) R²⁴ is hydrogen; alkyl; alkenyl; heteroalkyl; heteroalkenyl; a carbocyclic ring; a heterocyclic ring; -SO₃H; -C(=O)R²⁵; or, when R¹⁸ is -CH(N(R²⁴)R²¹)(R¹⁷), R²⁴ may comprise a moiety bonded to R²¹ to form a heterocyclic ring; and
- 85 (c) R²⁵ is R¹⁷, NH(R¹⁷), N(R¹⁷)(R²⁶), O(R²⁶), or S(R²⁶); where R²⁶ is alkyl, alkenyl, a carbocyclic ring, a heterocyclic ring, or when R²⁵ is N(R¹⁷)(R²⁶), R²⁶ may be a moiety bonded to R¹⁷ to form a heterocyclic ring; and
- 90 (7) R²¹ is R²⁹ or hydrogen; where R²⁹ is alkyl; alkenyl; arylalkyl; heteroalkyl; heteroalkenyl; heteroarylalkyl; a carbocyclic ring; a heterocyclic ring; or, when Y is N(R²⁴)R²¹ and R²¹ is R²⁹, R²¹ and R²⁴ may together comprise a heterocyclic ring
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including the nitrogen atom to which R²⁴ is bonded;

- 105 (B) R¹¹ is hydrogen, halogen, alkoxy, or R²⁷C(=O)NH-, where R²⁷ is hydrogen or alkyl;
- (C) bond "a" is a single bond or is nil; and bond "b" is a single bond, a double bond, or is nil; except bond "a" and bond "b" are not both nil;
- 110 (D) R¹² is -C(R^{8a})-, or -CH₂-R²⁸-; where R²⁸ is -C(R^{8a}), -O-, or -N-, and R²⁸ is directly bonded to N" in Formula (II) to form a 5-membered ring; except, if bond "a" is nil, then R¹² is
- (1) -C(R^{8a})(X¹)-, where
- 115 (i) X¹ is -R²¹; -OR³⁰; -S(O)_rR³⁰, where r is an integer from 0 to 2; -OC(=O)R³⁰; or N(R³⁰)R³¹; and
- (ii) R³⁰ and R³¹ are, independently, alkyl, alkenyl, carbocyclic ring or heterocyclic ring substituents; or R³⁰ and R³¹ together comprise a heterocyclic ring including the nitrogen atom to which R³⁰ and R³¹ are bonded; or
- 120 (2) -CH₂-R³²-; where R³² is -C(R^{8a})(R²¹), -O-, or -NR^{8a}, and R³² is directly bonded to N" in Formula (II) to form a 5-membered ring;
- 125 (E) (1) if bond "b" is a single bond, R¹³ is -CH(R³³)-; or, -C(O)NHSO₂-, if bond "a" is nil; or -C*(R³³)- if R¹⁴ contains a R³⁶ moiety; where R³³ is hydrogen or COOH, and C* is linked to R³⁶ to form a 3-membered ring;
- 130 (2) if bond "b" is a double bond, R¹³ is -C(R³³)=; or
- (3) if bond "b" is nil, R¹³ is hydrogen, -SO₃H, -PO(OR³⁴)OH, -C(O)NHSO₂N(R³⁴)(R³⁵), -OSO₃H, -CH(R³⁵)COOH, or -OCH(R³⁴)COOH; where R³⁴ is hydrogen, alkyl, alkenyl, a carbocyclic ring, or a heterocyclic ring; and R³⁵ is
- 135

- hydrogen, alkyl, alkenyl, or -NHR^{8a}; or, if R¹³ is -C(O)NHSO₂N(R³⁴)(R³⁵), R³⁴ and R³⁵ may together comprise a heterocyclic ring including the nitrogen to which R³⁴ and R³⁵ are bonded; and
- 140 (F) (1) if bond "a" or bond "b" is nil, then R¹⁴ is nil;
- 145 (2) if bond "a" and "b" are single bonds, R¹⁴ is -W-C''-C(R^{8a})-R³⁷-, or -W-C''(R³⁶)-R³⁷-, or
- (3) if bond "a" is a single bond and bond "b" is a double bond, R¹⁴ is -C(R^{8a})(R³⁸)-W-C''-R³⁷-;
- 150 -W'-C(R^{8a})(R³⁸)-C''-R³⁷-; or -W-C''-R³⁷-; where
- (a) W is O; S(O)_s, where s is an integer from 0 to 2; or C(R³⁸), where R³⁸ is hydrogen, alkyl or alkoxy;
- 155 (b) W' is O; or C(R³⁸);
- (c) R³⁶ hydrogen; alkyl; alkenyl; -COOH; or, if R¹³ is -C*(R³³), R³⁶ may be linked to C* to form a 3-membered carbocyclic ring;
- 160 (d) R³⁷ and is nil, alkyl, alkenyl, a carbocyclic ring, or a heterocyclic ring; and
- (e) C'' is directly bonded to R¹³ to form a 5- or 6-membered ring; and
- 165 (III)(A) L is -C(=O)-, and is bonded to L³ and L⁴
- (B) L¹ is L³ or R¹⁵L³; where
- (1) L³ is nitrogen;
- (2) R¹⁵ is alkyl, alkenyl, heteroalkyl, a heterocyclic ring, a carbocyclic ring, or R¹⁵ together with L³ is a heteroalkyl or a heterocyclic ring; and
- 170

- (3) L¹ is bonded to Q at the point of attachment of R¹, R⁶ or R⁷, whichever is nil;
- (C) L² is L⁴, -X²_t-R³⁹-L⁴, or -X³_t-R³⁹-L⁴; where
- 175 (1) L⁴ is oxygen;
- (2) X² is oxygen, or S(O)_v, where v is 0, 1, or 2;
- (3) X³ is nitrogen; N(R⁴⁰); N⁺(R⁴¹)(R⁴²); or R⁴³-N(R⁴¹); and is linked to R¹⁴ by a single or double bond; or, if R¹⁴ is nil, X³ is linked to B by a single or double bond; where
- 180 (a) R⁴⁰ is R^{8a}; -OR^{8a}; or -C(=O)R^{8a};
- (b) R⁴¹ and R⁴² are, independently, hydrogen; alkyl; alkenyl; carbocyclic rings; heterocyclic rings; or, if R⁶ is R¹⁶X, then R⁴¹ and R⁴² together with Q may comprise a heterocyclic ring as R¹⁶;
- 185 (c) R⁴³ is N(R⁴¹), oxygen or sulfur;
- (4) t is 0 or 1;
- 190 (5) R³⁹ is alkyl, alkenyl, heteroalkyl, heteroalkenyl, a carbocyclic ring, or a heterocyclic ring; and
- (6) (a) if bond "a" or bond "b" is nil, then L² is bonded directly to R¹² or R¹³; or
- 195 (b) if bond "a" and bond "b" are not nil, then L² is bonded to R¹⁴;

and pharmaceutically-acceptable salts and biohydrolyzable esters thereof, and hydrates thereof;

comprising the steps of:

- 200 (1) Reacting a lactam compound of the formula B-L⁴-H with phosgene to form an intermediate compound of the formula B-L⁴-C(=O)-Cl; and
- (2) Coupling said intermediate compound with a quinolone compound of the formula Q-L³-R⁴⁴; wherein R⁴⁴ is hydrogen, Si(R⁴⁵)₃, or Sn(R⁴⁵)₃; and R⁴⁵ is lower alkyl.
- 205

2. A process, according to Claim 1, additionally comprising
 - (a) a step, prior to said reacting step, wherein an ester of said lactam compound is formed;
 - (b) a step, prior to said coupling step, wherein an ester of said quinolone compound is formed; and
 - (c) deprotection steps, after said coupling step, wherein said esters are removed.
3. A process, according to Claim 1, wherein said coupling step comprises adding a solution containing said quinolone compound to a solution containing said intermediate compound.
4. A process, according to Claim 3, wherein said solutions are in a halocarbon solvent.
5. A process, according to Claim 4, wherein said halocarbon solvent is selected from the group consisting of methylene chloride, chloroform, dichloroethane, and mixtures thereof.
6. A process, according to Claim 3, wherein said reacting step and said coupling step are performed at a temperature of from about -80°C to about 0°C .
7. A process, according to Claim 6, wherein said temperature is from about -80°C to about -40°C .
8. A process, according to Claim 6, wherein R^{44} is $\text{Si}(\text{R}^{45})_3$.
9. A process, according to Claim 3, wherein R^{14} is $-\text{W}-\text{C}^{\text{m}}-\text{R}^{37}-$.
10. A process, according to Claim 9, wherein W is $\text{S}(\text{O})_s$.
11. A process, according to Claim 10, wherein A^1 is $\text{C}(\text{R}^7)$, A^2 is $\text{C}(\text{R}^2)$, and A^3 is $\text{C}(\text{R}^5)$; or A^1 is nitrogen, A^2 is $\text{C}(\text{R}^2)$, and A^3 is $\text{C}(\text{R}^5)$.

12. A process, according to Claim 11, wherein A¹ is C(R⁷), A² is C(R²), and A³ is C(R⁵).

13. A process, according to Claim 11, wherein R³ is nil and comprises a bond to L¹.

14. A process, according to Claim 11, wherein R⁶ is nil and comprises a bond to L¹.

15. A process, according to Claim 11, wherein said quinolone compound is:

1-Cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-piperaziny-quinoline-3-carboxylic acid;

5 1-Cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-piperaziny-quinoline-3-carboxylic acid allyl ester;

1-Cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-piperaziny-quinoline-3-carboxylic acid diphenylmethyl ester;

10 1-Cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-piperaziny-quinoline-3-carboxylic acid t-butyl ester;

1-Cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-piperaziny-quinoline-3-carboxylic acid 2,2,2-trichloroethyl ester;

7-(3-Amino-1-pyrrolidinyl)-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-quinoline-3-carboxylic acid;

15 7-(3-Amino-1-pyrrolidinyl)-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-quinoline-3-carboxylic acid allyl ester;

7-(3-Amino-1-pyrrolidinyl)-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-quinoline-3-carboxylic acid allyl ester;

20 5-Amino-7-(3-amino-1-pyrrolidinyl)-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-quinoline-3-carboxylic acid allyl ester;

5-Amino-1-cyclopropyl-6,8-difluoro-1,4-dihydro-7-(2,6-dimethyl-4-piperazinyl)-4-oxo-quinoline-3-carboxylic acid;

7-(3-Amino-1-pyrrolidinyl)-1-(2,4-difluorophenyl)-6-fluoro-1,4-dihydro-4-oxo-1,8-naphthyridine-3-carboxylic acid allyl ester; or

25 7-[3-(t-Butyloxycarbonyl)amino-1-pyrrolidinyl]-1-cyclopropyl-6,8-difluoro-1,4-dihydro-5-hydrazino-4-oxo-quinoline-3-carboxylic acid allyl ester.

16. A process, according to Claim 11, wherein lactam compound is:

5 [5R-[5a,6a]]-6-[(R)-1-(t-butyl dimethylsilyloxy)ethyl]-3-hydroxymethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid allyl ester;

[5R-[5a,6a]]-6-[(R)-1-[(allyloxycarbonyl)oxy]ethyl]-3-hydroxymethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid allyl ester;

10 [5R-[5a,6a]]-6-[(R)-1-[(2,2,2-trichloroethyloxycarbonyl)oxy]ethyl]-3-hydroxymethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid 2,2,2-trichloroethyl ester;

[5R-[5a,6a]]-6-[(R)-1-(t-butyl dimethylsilyloxy)ethyl]-3-hydroxymethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid diphenylmethyl ester;

15 [5R-[5a,6a]]-6-[(R)-1-(t-butyl dimethylsilyloxy)ethyl]-3-hydroxymethyl-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid t-butyl ester;

20 [5R-[4b,5a,6a]]-6-[(R)-1-(t-butyl dimethylsilyloxy)ethyl]-3-hydroxymethyl-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid allyl ester;

[5R-[5a,6a]]-6-[(R)-1-(t-butyl dimethylsilyloxy)ethyl]-3-(2-hydroxyethylthio)-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid allyl ester; or

25 [5R-[4b,5a,6a]]-6-[(R)-1-(t-butyl dimethylsilyloxy)ethyl]-3-(2-hydroxyethylthio)-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic acid allyl ester.

17. A process, according to Claim 1, wherein said antimicrobial compound is:

5 [5R-[5a,6a]]-3-[[[4-(3-Carboxy-1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-quinoliny)-1-piperazinyl]carbonyloxy]methyl]-6-[(R)-1-hydroxyethyl]-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

10 [5R-[4b,5a,6a]]-3-[[[4-(3-Carboxy-1-cyclopropyl-6-fluoro-1,4-dihydro-4-oxo-7-quinoliny)-1-piperazinyl]carbonyloxy]methyl]-6-[(R)-1-hydroxyethyl]-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

[5R-[5a,6a]]-3-[[[4-(3-Carboxy-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-7-quinoliny)-(S)-3-pyrrolidinyl]amino]-carbonyloxy]methyl]-6-[(R)-1-hydroxyethyl]-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

15 [5R-[4b,5a,6a]]-3-[[[4-(3-Carboxy-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-7-quinoliny)-(S)-3-pyrrolidinyl]amino]-carbonyloxy]methyl]-6-[(R)-1-hydroxyethyl]-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

20 [5R-[5a,6a]]-3-[[[4-[3-Carboxy-1-(2,4-difluorophenyl)-6-fluoro-1,4-dihydro-4-oxo-1,8-naphthyridin-1-yl]-(S)-3-pyrrolidinyl]amino]-carbonyloxy)methyl]-6-[(R)-1-hydroxyethyl]-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

25 [5R-[4b,5a,6a]]-3-[[[4-[3-Carboxy-1-(2,4-difluorophenyl)-6-fluoro-1,4-dihydro-4-oxo-1,8-naphthyridin-1-yl]-(S)-3-pyrrolidinyl]amino]-carbonyloxy)methyl]-6-[(R)-1-hydroxyethyl]-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

30 [5R-[5a,6a]]-3-[[[4-(5-Amino-3-carboxy-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-7-quinoliny)]-2,6-dimethyl-4-piperazinyl]carbonyloxy)methyl]-6-[(R)-1-hydroxyethyl]-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

35 [5R-[4b,5a,6a]]-3-[[[4-(5-Amino-3-carboxy-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-7-quinoliny)]-2,6-dimethyl-4-piperazinyl]carbonyloxy)methyl]-6-[(R)-1-hydroxyethyl]-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt;

40 [5R-[5a,6a]]-3-[[[2-[7-((S)-3-Amino-1-pyrrolidinyl)-3-carboxy-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-5-quinoliny)]-1-hydrazino]-carbonyloxy)methyl]-6-[(R)-1-hydroxyethyl]-7-oxo-4-thia-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt; or

45 [5R-[4b,5a,6a]]-3-[[[2-[7-((S)-3-Amino-1-pyrrolidinyl)-3-carboxy-1-cyclopropyl-6,8-difluoro-1,4-dihydro-4-oxo-5-quinoliny)]-1-hydrazino]-carbonyloxy)methyl]-6-[(R)-1-hydroxyethyl]-4-methyl-7-oxo-1-azabicyclo[3.2.0]hept-2-ene-2-carboxylic Acid, Disodium Salt.